HAWAII AGRICULTURAL EXPERIMENT STATION

E. V. WILCOX, SPECIAL AGENT IN CHARGE.

ANNUAL REPORT

OF THE

HAWAII AGRICULTURAL EXPERIMENT STATION

FOR

1909

UNDER THE SUPERVISION OF

OFFICE OF EXPERIMENT STATIONS.

U. S. DEPARTMENT OF AGRICULTURE.

HONOLULU:
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HAWAII AGRICULTURAL EXPERIMENT STATION, HONOLULU.

[Under the supervision of A. C. TRUE, Director of the Office of Experiment Stations, United States Department of Agriculture.]

WALTER H. EVANS, *Chief of Division of Insular Stations, Office of Experiment Stations.*

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LETTER OF TRANSMITTAL

HAWAII AGRICULTURAL EXPERIMENT STATION,
HONOLULU, HAWAII, Feb. 16, 1910.

SIR: I have the honor to transmit herewith and to recommend for publication the Annual Report of the Hawaii Agricultural Experiment Station for the fiscal year 1909.

Respectfully, E. V. WILCOX,
Special Agent in Charge.

DR. A. C. TRUE,
Director Office of Experiment Stations,
U. S. Department of Agriculture, Washington, D. C.

Publication recommended.
A. C. TRUE, *Director.*

Publication authorized.
JAMES WILSON, *Secretary of Agriculture.*

CONTENTS.

ILLUSTRATIONS.

TEXT FIGURES.

PLATES.

ANNUAL REPORT OF THE HAWAII AGRICULTURAL EXPERIMENT STATION FOR 1909

SUMMARY OF INVESTIGATIONS

By E. V. Wilcox, *Special Agent in Charge.*

DIVERSIFIED AGRICULTURE.

During the past year gratifying success has been had in developing a substantial interest in the diversification of agriculture in the Territory. The apparent hesitation which has frequently been shown by citizens of the Territory in engaging in general lines of agriculture has evidently been due not to any doubt as to the possibility of raising a great variety of crops, but to a lack of specific experimental data as to where the best seed may be obtained, the best cultural methods for these crops, and facilities for marketing them. All of our citizens, who are most actively interested in the development of the Territory, have gladly welcomed any information or experimental data which may serve to establish, on a business foundation, any line of agricultural industry which promises commercial success. This statement is fully justified by the active interest shown in the pineapple industry, the development of rubber plantations, the rapid spread of cotton planting, the cooperation of land owners and growers in making the rice crop more profitable, and in the general activity in increasing the acreage of forage crops, garden crops, and miscellaneous fruits and crops.

The area planted to corn is being rapidly enlarged and satisfactory returns are everywhere being reported. From large areas average yields of forty bushels per acre of corn have been obtained under rainfall conditions varying from 5 to 240 inches per year, and at altitudes ranging from sea-level to 5,000 feet.

The acreage of alfalfa, sorghum, Rhodes grass, Para grass, cowpeas, jack beans, soy beans, and other forage crops is increasing at a corresponding rate.

Not only are these crops, which are regarded as the mainstay of agriculture in temperate climates, considered as worth while in themselves, but their importance in systems of rotation is being recognized, and this means that the further extension of the area devoted to miscellaneous crops will proceed more rapidly in the future than in the past.

The definite policy has been adopted of making the chief work of the members of the staff that of investigation, in order that actual contributions may be made to the sum total of agricultural science. Naturally, however, some attention must be given from time to time to miscellaneous requests for practical information from farmers. An attempt is made, however, to prevent this work from interfering too greatly with the regular lines of investigation.

CHEMICAL INVESTIGATIONS.

The chemist and assistant chemist have confined their attention during the year almost exclusively to the study of pineapple soils, research on the fertilization and nutrition of rice, and fertilizer experiments with cotton. A preliminary report on the relation of manganese to the growth of pineapples has already been published in Press Bulletin 23. It appears, from further study of pineapples, that this plant is exceedingly sensitive to soil conditions, and does not thrive satisfactorily when planted continuously on the same soil. The poor results from a one-crop system are not yet definitely explained, but are partly due to the depletion of the organic matter in the soil from this system, and the consequent packing of the lower layers of the soil. When it is remembered that these soils contain unusually large amounts of ferric hydrate, which acts very much like clay, it is easily understood that with a heavy rainfall the soil becomes saturated with water and cannot be properly aerated by superficial cultivation.

The fertilizer experiments with pineapples are not yet completed for the reason that eighteen months are required from the time of planting until the first harvest. At present, however, the growth of the plants indicates clearly that certain combinations of fertilizers are very effective, while others are prac-

tically without result. The scientific explanation of these results, and practical conclusions to be drawn from them, must be postponed until the experiment is completed.

Plans have been made for putting in two drainage experiments. There is abundant evidence that some of the poor results obtained from pineapples, in restricted areas, are due to lack of drainage. No tile drainage has hitherto been used in the islands, and it is believed to be worth while to test its efficiency under our conditions.

A considerable number of soil samples have been analyzed in order to secure data on the distribution of manganese in the pineapple fields. As indicated in the preliminary report, already referred to, black soils contain relatively high percentages of manganese and such soils have proved unsuitable for pineapple culture. It has been found that the manganese in this soil is exceedingly soluble; that in the growth of pineapples it undergoes a higher oxidation, and that this change is detrimental to plant growth. It is hoped that during the present year we may find a scientific explanation of the effect of manganese upon pineapple plants and upon the plant nutrients in the soil.

An important experiment has been undertaken with rice to determine the period of growth in which various nutrients are absorbed and their inter-relations with reference to the development of the plant. One series of cultures has already been completed, and analyses of various parts of the rice plant, at different stages of growth, are being made. The experiment will be repeated on another crop of rice in order to obtain further evidence on some of the data which have already appeared. It has been found that certain fertilizer materials affect the composition of rice as regards its nitrogen content.

The results thus far obtained from a fertilizer experiment on cotton indicate that the growth of the plants has been greatly increased by the use of phosphates.

COTTON INVESTIGATIONS.

Since the spring of 1908 considerable attention has been given to the investigation of the culture and breeding of cotton. In the experimental plats we have about 30 varieties of cotton, including Sea Island, Caravonica, Egyptian, Chinese, upland, and native cottons.

It has been found that all varieties of cotton grow here as perennials. In order to maintain a suitable form in the plants, it is desirable to pinch back the terminal buds or prune the plants. The removal of the old wood and trash helps in controlling insect troubles and makes it possible to throw the fruiting season at the desired time of the year. The operation of pruning is simple and not excessively time-consuming and can be recommended for commercial practice.

In obtaining pure strains of cotton, free from the effects of crossing, resort has been had to the use of cuttings. This has been found to be a very satisfactory way for propagating pure strains, and will be used more extensively in the future. Following upon the success had by one of the cotton growers of the Territory, a number of experiments in budding cotton have been made with satisfactory results. It seems to be no more difficult with cotton than with other plants which are commonly treated in this way.

The area planted to cotton during the past year was about 100 acres, but arrangements have already been made for planting somewhat more than a thousand acres during the coming year. All of the commercial ventures in planting cotton, thus far undertaken, have proved very encouraging. The climatic conditions, while exceedingly variable in different parts of the islands, are nearly all favorable to the growth of cotton up to at least an altitude of 800 feet, and within a range of rainfall of 20 to 100 inches.

ENTOMOLOGICAL INVESTIGATIONS.

The attention of the entomologist has been chiefly devoted to a study of cotton insects and plant lice. A bulletin on cotton insects has recently been published.[1] Leaf-eating caterpillars have been unusually injurious during the year and have made it necessary to devote some attention to these pests. Cutworms and army worms have attacked a great variety of crops, including rice and alfalfa, causing a good deal of damage, but fairly satisfactory methods of controlling these pests have been applied.

Arrangements have been made for introducing parasites of algaroba weevils, plant lice, and scale insects. The Bureau

[1] Hawaii Sta. Bul. 18.

of Entomology has already begun shipments of parasites and lady-birds for this purpose. In addition to this means of control, the Florida Experiment Station has undertaken to furnish us with cultures of parasitic fungi to aid us in keeping down scale insects and plant lice.

On account of the great prevalence of plant lice upon all sorts of cultivated and wild plants, particularly during the winter season, it has been thought desirable to make a special study of these pests. The entomologist has devoted much time to this problem. A fairly complete collection of the plant lice of the Territory has been made, and from a careful study of this collection, in connection with all available literature on the subject a synopsis of the Aphidae has been prepared in which all of the important species known to occur in Hawaii are described and details are given for their ready indentification. In this work a few new species were found and have been described.

HORTICULTURAL INVESTIGATIONS.

Much time has been given to methods of propagating citrus fruits and mangoes. The growers of these fruits have experienced considerable difficulty in successfully budding them. It appears that satisfactory results are to be obtained by adopting the ordinary method of budding citrus fruit, with an inverted "T". The lack of success in budding citrus fruit may be due to infertility of the soil, insufficient moisture, lack of vigor of the trees, and insects and fungus diseases. Attention must, therefore, be given to all of these points in order to get the best results. In this work it was found neccessary to give some attention to scale insects, aphids, cut-worms and other pests which may interfere with the success of budding. The use of kerosene emulsion was found unsatisfactory and too expensive, but far better results were obtained by fumigation. In budding mangoes the best results have been obtained from the application of the "shield" method with the inverted "T", using only well-matured wood and cutting the "T" and the "shield" very long, the former six or seven inches, and the latter, three or four inches. Gratifying success has also been obtained from inarch-in the case of the mango. A series of experiments is now under way in developing a more practical method for budding the avocado. It is certain that the production of commercial quant-

ities of fine mangoes and avocados depends primarily on practical methods of budding orchards devoted to these fruits.

An elaborate system of keeping laboratory and field records for the purpose of locating trees and plants upon which experiments are made, has been devised and will tend to render the keeping of records more convenient and satisfactory.

The use of cover crops in orchards during the winter appears to be quite necessary on slopes where excessive washing of the soil would otherwise occur. For this purpose, cowpeas and jack beans have given the best results. A series of experiments with a considerable variety of garden vegetables is in progress, but the results are not yet available.

On account of numerous requests from the mainland for dried roselle, an experiment was made in drying this fruit. It was found that the dried material could not be produced profitably at the price which the mainland dealers offered for it. Our experiments indicate that 12.8 pounds of the fresh fruit are required to produce one pound of dry calyces. It would appear more profitable, therefore, to use this fruit in a fresh state for the production of jams and jellies.

RICE INVESTIGATIONS.

In a fertilizer experiment with rice it was found that 200 pounds per acre of a complete fertilizer gave practically as large yields of paddy as did greater quantities up to 800 pounds. Moreover, the results were approximately the same whether applied before the crop was planted, or when well advanced in growth. A number of cooperative fertilizer tests were made for the purpose of testing, on a commercial scale, the results already obtained on the trial grounds, and to bring greater profits, if possible, from the rice industry. These experiments were entirely satisfactory, in so far as the results from the fertilizers were concerned, but were somewhat interfered with by the unusual insect troubles to which rice was subjected during the past year. The variety of rice, referred to in previous reports as No. 19, is now firmly established and has given excellent returns wherever it has been planted. Satisfactory progress is also being made with upland rice as a hay crop.

RUBBER INVESTIGATIONS.

During the past year tapping experiments were carried out on more than 400 rubber trees for the purpose of determining the yield which may be expected from rubber, the best methods of tapping, the possibility of economically using Japanese labor for this purpose, the time of day at which tapping should be made, the effects of tapping upon rubber trees, methods of coagulating latex, and the stimulating effect of fertilizers upon the flow of latex. These experiments indicate that the Ceara rubber tree in Hawaii may be planted on a commercial scale with the assurance of reasonable profit. A bulletin, covering these investigations, is now in press.

MISCELLANEOUS INVESTIGATIONS.

During the past year some attention was given to methods of grinding algaroba pods. These constitute one of the most important forage products of Hawaii, but on account of the indigestibility of the seeds, without grinding, a large part of the protein content of the pods was lost. A number of farmers had attempted to grind the pods, but had failed on account of their sticky nature. It was found, by laboratory experiments, that by slightly moistening the cracked pods and then drying them, they could be readily ground with any form of feed mill. The importance of a special mill for grinding algaroba pods in a fresh condition, was suggested to a local inventor and machinist, who has since perfected a machine which grinds the pods in a satisfactory manner. In devising this machine, the inventor adopted some of the ideas already developed in our work and cooperated with the station to the fullest extent. The use of these machines will undoubtedly become quite general and will add greatly to the available nutritive value of the algaroba.

In the perpetual conflict with weeds it is necessary to use every possible means which is efficient in destroying them. For this reason an experiment was made in destroying various weeds by means of carbon bisulphid. It was found that herbaceous as well as shrubby weeds could readily be destroyed by this chemical. A tablespoonful of carbon bisulphid, poured upon the stem, about six inches above the ground, will cause the death of such weeds as Oi, Crotalaria, prickly pear, lantana, and

guava within a period ranging from twenty-four hours to six weeks or two months. A press bulletin on this subject has recently been published.[1]

The federal funds, available for the use of this station, were supplemented at the last session of the territorial legislature by an appropriation of $10,000 for the biennial period, and an additional sum, to be allotted by a commission, from the surplus revenues of the Income Tax. This generous appropriation by the Territory will make it possible for the station to extend its work in various directions, particularly in the study of plant diseases, forage crops, and suitable rotations. Along this line, there is already in progress, or in contemplation, rotation or intercultural experiments with rubber, pineapples, cotton, rice, taro, etc.

[1] Hawaii Sta. Press Bul. 25.

REPORT OF THE ENTOMOLOGIST

By David T. Fullaway.

GENERAL INSECT NOTES.

The year has been very interesting from an entomological standpoint in showing some long-known pests in new roles and in broadening the knowledge of our insect fauna. At the beginning of the year some attention was given to the means of combating pineapple pests, in order, primarily, to reduce the losses occasioned by these pests, but more particularly to check their spread, and this work was followed up in the spring. Dipping and fumigating suckers and the liberal application of tobacco dust to the plants kept both mealy-bug (*Pseudococcus bromeliae?*) and the scale-bug (*Diaspis bromeliae*) at a minimum. It would be well if the growers would adopt a uniform method in attempting to control these two pests.

Aside from work of a purely investigational character, numerous inquiries in regard to insect pests of agricultural crops and means of combating them have been answered by correspondence. In some instances personal inspection of the conditions was made and advice offered. The station's collection of economic insects has been maintained and much material added.

In January, 1909 the entomologist, Mr. D. L. Van Dine, secured leave of absence to visit the mainland of the United States, and on March 1st presented his resignation in order to accept a position with the United States Bureau of Entomology in the southern field crop insect and tick investigations at Dallas, Texas. The writer, who was appointed assistant entomologist at the station on August 17th, succeeded Mr. Van Dine as entomologist.

The chief investigation of the year has been of the insects affecting the cotton plant in Hawaii, the results of which are contained in Bulletin 18. This work was necessitated by the increasing interest in the possibilities of cotton growing, following the station's cultural experiments extending over three years. The cotton bollweevil (*Anthonomus grandis*), the most destruc

tive of the insect enemies of cotton in the United States, is not found in Hawaii, and the cotton bollworm (*Heliothis obsoleta*), while here, is so heavily parasitized that it is not likely to become an important factor in cotton production. The most destructive cotton pest is probably an Indian introduction, the larva of a Tineid moth, *Gelechia gossypiella.* This bollworm in India, according to Lefroy, may cause an annual loss of $4,000,000. Here, from 5% to 50% of the crop is damaged by the worm, which attacks and destroys the young ovules, preventing the formation of bolls, or more frequently enters maturing fruit, soiling the lint and causing premature opening and rotting. The worm is attacked by a Braconid parasite (*Chelonus blackburni,*) which is more or less effective in reducing its numbers. Other pests of a more or less serious nature were found. Seedling plants are attacked by wireworms and cutworms, commonly injurious to nearly all agricultural crops. A greenfly (*Aphis gossypii*) intermittently attacks the plants and at times is very destructive. It is controlled by spraying and by predaceous enemies (Coccinellids), of which there are many introduced species. The Japanese beetle (*Adoretus tenuimaculatus*) at times attacks the foliage but does not appear to be a serious pest. Two virulent Coccid species, *Pseudococcus virgatus* and *P. filamentosus,* are at times pests of cotton and greatly injure the plants. They are being constantly held in check by predaceous enemies (Coccinellids), but can nearly always be found in the cotton field doing considerable damage. There are many minor pests, the injury from which is more or less negligible, as *Archips postvittanus* and *Amorbia emigratella,* Tortricid moths whose larvae fold the leaves, a species of Thrips injuring the buds, and a species of Tetranychus (red spider) on the foliage. The employment of artificial remedies has been advised in some cases, but on the whole, or on a large scale, is considered impractical. As stated, many insects are kept in check and their injuries greatly lightened by natural enemies. The introduction of other parasites and predators is recommended, as it is believed that much may be hoped from them.

The winter and spring were marked by excessive outbreaks of cutworms. Three species were especially bad, *Agrotis ypsilon, Heliophila unipuncta,* and *Spodoptera mauritia.* For the first time in the history of rice cultivation in the islands this cereal was attacked by *H. unipuncta.* From all the rice-

producing sections of the islands the reports indicated serious losses due to the ravages of *H. unipuncta* larvæ. Early fruiting and late maturing crops escaped, but the bulk of the rice, maturing in the latter part of May, was very badly affected. In the early part of June the entomologist visited most of the rice fields on Oahu, and while some seemed to have suffered less than others, the presence of the worm, to some extent, was established in all. At two places on Kauai, and at Kalihi, Punaluu, Hauula, and Kailua on Oahu, the damage was very severe, amounting to from 10% to 60% of the crop.

Another insect of economic importance, a Tortricid moth close to *Archips* [1] (there are undoubtedly several species involved, one being *A. postvittanus,* which, however, is parasitized in the egg-stage), is increasing enormously and gives promise of being a serious pest of fruit. It attacks a great variety of soft and succulent fruits—citrus, alligator pear, guava, passion flower vine, tomato, and still others. Of these, only the citrus, alligator pear, and tomato are fruits cultivated for the market, and none is grown in a large way. If citrus culture is undertaken on an extensive scale, this pest must be taken into account, as along with other enemies of citrus fruits, the damage to the crop will be very heavy. Spraying with arsenate of lead was recommended and used with effect.

Some attention was given to beekeeping, and it was proposed to investigate the possibility of increasing the production of wax by new methods of manipulation. Suitable arrangements for this work have not yet been made.

The introduction of parasites of the beanweevils, of which several species are serious pests, attacking the pods of *Prosopis juliflora* and other leguminous plants which are used chiefly as animal fodders, has been undertaken and from the two or three shipments of parasites already received a large Braconid (*Heterospilus* sp.) has been bred in numbers and liberated. Other shipments of parasites are expected and much is hoped from them. These parasites were received from Texas, through the cooperation of the United States Bureau of Entomology, and the station is especially indebted to Dr. W. D. Hunter, in

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[1] Note. This moth has been described by A. Busck in Proc. Ent. Soc. Wash., vol. XI, p. 201 (1909), from specimens sent from here, as *Amorbia emigratella*, and is supposed to be a recent immigrant from Mexico.

charge of the southern field crop insect and tick investigations of the bureau, for his able assistance and great personal interest in an effort to introduce insects which may be of great benefit to the agricultural industries of the islands. For this work, an insect-proof house was built in which the parasites can be safely handled. It is desired later to introduce parasites of other insect pests, especially aphids and coccids. Cultures of entomophagous fungi have also been received from Florida, through the courtesy of Prof. P. H. Rolfs, Director of the Florida Agricultural Experiment Station, and will be tried on our destructive Coccidæ in the fall.

After the first blossoming of the algaroba, numerous reports were received at the station of the destructive work of a caterpillar on the algaroba blossoms. For several years the larva of a Phycitid moth, *Cryptoblabes aliena,* has been known to affect the blossoms of the keawe, but it was not believed to be especially destructive. An investigation showed that there were two distinct caterpillars working on the blossoms, the Cryptoblabes larva and the caterpillar of a moth close to Archips.[1] As far as observation goes, the wandering of the caterpillars among the blossoms seems to prevent the natural formation of pods, and the result is likely to be a very short crop of beans. Reports from different sections of the islands indicate this, and as the stockmen depend largely upon the keawe bean for winter fodder, the serious nature of these two pests is at once appreciated. A more thorough investigation of the matter is contemplated.

The three or four last months of the year were devoted to the collection and systematic study of the Aphidæ present in the islands. The results of this work are given in the following "Synopsis of Hawaiian Aphidæ."

SYNOPSIS OF HAWAIIAN APHIDAE.

In the investigation of the Hawaiian fauna and its systematic elaboration, some of the groups of smaller insects, of great economic importance, received practically no attention whatever, due partly to difficulties in the way of preservation of specimens, and in some cases to lack of scientific interest in insects evidently not indigenous. The Aphidæ, or plant lice,

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[1] vide fn. p. 19.

among others, suffered such neglect, although Kirkaldy [1] twice gave lists of known species and described two species as new. The present paper, in which the number of species is increased to 21, four of which are described as new, represents as thorough a study of the family as was possible with limited facilities and time. The writer's collecting was almost entirely confined to Honolulu and its adjacent mountains and extended over less than a year. More extensive collection might have added to the list. The writer acknowledges with thanks the help and encouragement of many co-workers, and is under especial obligation to Mr. Kirkaldy for the loan of literature.

KEY TO GENERA.

1.	Antennæ of seven segments	2
	Antennæ of less than seven segments	8
2.	Antennæ inserted on a frontal tubercle	3
	Antennæ inserted directly on the head	6
3.	Frontal tubercles approximate, head grooved	*Macrosiphum*
	Frontal tubercles not approximate, head smooth or convex	4
4.	Nectaries cylindrical	*Myzus*
	Nectaries more or less clavate, at least not cylindrical	5
5.	Second branch of cubital vein distorted so as to form a closed-cubital cell	*Pentalonia*
	Second branch of cubital vein not distorted, wing venation normal	*Rhopalosiphum*
6.	Cubital vein only once forked	*Toxoptera*
	Cubital vein twice forked	7
7.	Nectaries longer than broad, cylindrical	*Aphis*
	Nectaries shorter than broad	*Myzocallis*
8.	Antennæ with six segments	*Eriosoma* (*Schizoneura*)
	Antennæ with five segments	*Cerataphis*

MACROSIPHUM *Passerini*.

Antennæ nearly always longer than body, on distinct and approximate frontal tubercles; seventh joint mostly longer than

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[1] vide Proc. Haw. Ent. Soc., vol. 1, pt. 3, p. 100 (1907), pt. 5, p. 206 (1908).

the third. Wings large, legs long and slender, nectaries long, cylindrical, tail long, ensiform.

There are five species of this genus found in Hawaii, to be distinguished as follows:

1. General color black, with capitate hairs............*M. kirkaldyi*
   General color green, without capitate hairs............ 2
   General color brownish or yellowish........................ 3
2. Greenish without darker markings on abdomen....*M. trifolii*
   Greenish with dark lateral and dorsal markings....*M. rosae*
3. General color dark reddish or brownish and hairy ....*M. sanborni*
   General color yellow with horseshoe-shaped marking on dorsum of abdomen of apterous female..*M. circumflexa*

Macrosiphum kirkaldyi n. sp.

Apterous female. Dull black, the dorsum bearing transverse rows of white capitate hairs. Sometimes a tinge of dark red on head. Eyes dark red. 1st and 2nd segments of antennæ black, 3rd, 4th and 5th pale with black tips, 6th and 7th dusky black. Legs long and pale, the tips of tibiæ slightly brownish, tarsi black. Nectaries moderately long, pale, black at base. Tail black. Length 1.4 mm.

Winged female. Dull black, thoracic tubercles and head having at times a copperish tinge, in front of and behind prothorax bluish. Eyes dark red, ocelli clear and bordered with black. Antennæ dusky, segments 1 and 2, 6 and 7, and tips of 3, 4 and 5 black. Legs pale, tips of femora, tibiæ, and tarsi black. Nectaries moderately long, cylindrical, wider at base than at apex, mouth conspicuously rimmed, pale, black at base. Tail about half as long as nectaries, ensiform, edges serrate, with two backward-pointing bristles on each side, black, subanal plate fringed with white. Rostrum reaching 3rd coxæ, pale with black tip and base. Wings clear, highly iridescent, veins black and heavily shaded, stigma short, broad, shaded with black, venation abnormal, only one branch to cubital, stigmatic vein much curved, uniting with cubital and branch for part of its length. Antennæ extending beyond the body about one-third of its length, glabrous, 7th segment longer than 3rd, 4th and 5th subequal, 1st, 2nd and 6th smaller than 4th or 5th and

subequal. Third segment with 9-11 circular sensoria, 4th with 4, 5th with 1-4, 6th with one large sensorium. Antennæ on distinct tubercles and close together, tubercles gibbous on inner

FIG. 1.—*Macrosiphum kirkaldyi* wingless viviparous female, enlarged, (original)

apical angle. Body covered with white capitate hairs. Length of body 1.25 mm. Length of antennæ 1.65 mm. Expanse of wings 4.5 mm.

Hab. Oahu, Tantalus (2000), Niu (2000), Palolo (1500) (O. H. S., D. T. F.); on *Acrostichum reticulatum.*

Macrosiphum trifolii Perg.

M. trifolii Pergande, Bul. 44, U. S. Bur. Ent., p. 21 (1904).

Apterous female. Light pea green and polished or somewhat pruinose, yellowish green towards head. Eyes red. An-

tennæ black except segments 1 and 2, which are yellowish green (in immature specimens segments 3, 4 and 5 are paler, only the tips black). Legs long, femora greenish at base, apically brownish, tibiæ brownish to black tip, tarsi black. Nectaries brownish in middle changing to black at apex and to green at base. Tail pale. Length 2.5 mm.—3.25 mm.

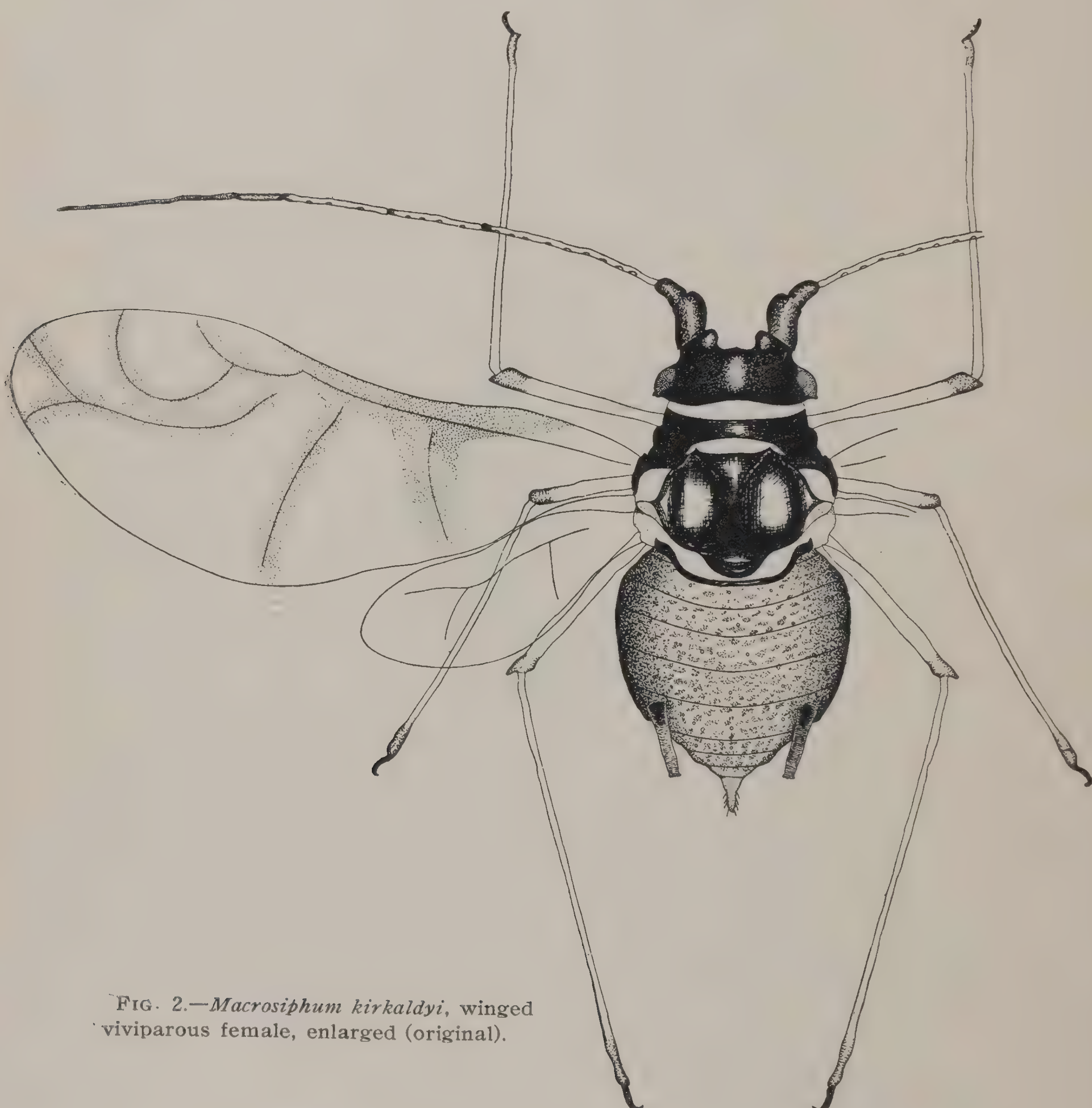

FIG. 2.—*Macrosiphum kirkaldyi*, winged viviparous female, enlarged (original).

Winged female. Light green, head and thoracic tubercles yellowish green. Eyes reddish brown, ocelli close to eye, clear and bordered with black. Antennæ black distally from near base of 3rd segment, 1st and 2nd segments and base of 3rd greenish yellow. Apical half of femora, tips of tibiæ and tarsi black, the remaining portions pale. Nectaries long and slender,

cylindrical, larger at base than at apex, dusky to black and greenish at base. Tail about half as long as nectaries, ensiform, densely covered with minute sharp spines and with four backward-curved hairs on each side, pale. Wings clear, veins thin and brownish, stigma long, narrow and greenish, venation normal. Antennæ extending to or slightly beyond tip of nectaries, hairs sparse and simple, seventh segment longer than third, fourth less than third, fifth less than fourth, sixth, first and second small. Sixteen small circular sensoria on third segment, one large circular sensorium at tip of fifth. Length of body 2.25—3.25 mm. Length of antennæ 3.37 mm. Expanse of wings 8.5 mm.

Hab. Oahu, Honolulu, Tantalus (2000) (D. T. F.); on *Sonchus oleraceus.*

Macrosiphum rosae (Linn.)

Aphis rosae Linn. Syst. Nat. 1, 2, 734 (1735)

Siphonophora rosae Koch. Pflanzenl. 178 (1854-1857)

Apterous female. Shining green. Eyes red. Antennæ long, as long as body, dusky. Legs long, yellowish green, tips of femora, tibiæ and tarsi black. Body long, ovate. Nectaries very long, reaching to or beyond tip of tail, curved, black. Tail long, ensiform, yellow. Length 2.25 mm.

Winged female. Green, head and thorax olive brown, prothorax greenish with darker transverse band. Abdomen lighter green with a row of five dark spots on each lateral margin, and obscure markings on the dorsum between segments two and five. Eyes red. Antennæ black except 2nd segment and base of third. Legs of moderate length, lemon yellow, the apices of femora, tibiæ and tarsi black. Nectaries long, thin, black, reaching to tip of tail, wider at base than at apex. Tail long, light yellow, ensiform, and bent slightly upward. Wings ample, clear, insertions and cubitus yellow. Stigma greenish, veins black, venation normal. Antennæ as long as or slightly longer than body, segments 3 and 7 subequal, 4th much shorter than the preceding but longer than 5th. Third segment with 14 circular sensoria, 8 on 4th segment, 1 on 5th, 1 on 6th. Length of body 1.85 mm. Length of antennæ 1.9 mm.

Hab. Oahu, Honolulu (D. T. F.); Hawaii, Mana (3500), Puuopelu (2000) (G. W. K.); on cultivated roses.

Macrosiphum sanborni Gillette.

M. sanborni Gillette. Can. Ent. 40, p. 65 (1908)

M. chrysanthemi (Oest.) Sanborn Kans. Univ. Sci. Bul., vol. 3, no. 1, p. 73 (1904)

Apterous female. Dark red, almost black, and polished, thorax lighter red, distinctly carinated, the body bearing transverse rows of hairs. Eyes dark red. Antennæ as long as or longer than the body, 3rd segment (except at tip) and base of 4th pale to yellow, the rest black. Legs stout, tip of femur, base and tip of tibia and tarsus black, rest pale to yellow. Nectaries vasiform, moderately long with wide base and narrow mouth, black. Tail about same length as nectaries but extending beyond them, concolorous, the chitinized portions black, ensiform, constricted at middle, with four backward curved hairs. Larvæ cherry red. Length 1.75 mm.

Winged female. Dark cherry brown, the head nearly black, thorax lighter red, tip of abdomen yellowish, body quite hairy, the hairs arranged in transverse rows. Eyes dark red. Antennæ black except base of 3rd segment which is yellow. Legs as in apterous form. Nectaries moderate, cylindrical but wider at base than at apex, with conspicuously rimmed mouth, black. Tail ensiform, upturned, black, about as long as nectaries but extending beyond them, and hairy. Rostrum reaching 2nd coxæ and black. Wings long and slender, extending beyond body by half their length, clear, iridescent, veins thin, dusky, stigma long and thin, yellow, venation normal. Antennæ as long as or longer than the body, more or less glabrous, 3rd segment longest, slightly longer than 7, about twice as long as 5, which is slightly less than 4. Third segment (and 4th) tuberculate with many sensoria, 5 and 6 each with one. Length of body 1.8 mm. Length of antennæ 2 mm.

Hab. Oahu, Honolulu (D. T. F.); on cultivated chrysanthemums.

Macrosiphum circumflexum (Buckt.)

Siphonophora circumflexa Buckton. Mon. Brit. Aphidæ, vol. 1, p. 130.

Apterous female. Yellow with black markings as follows: on prothorax toward lateral margins large spot outward and forward, a smaller one inward and backward, meso and meta-

thorax each large transverse marking, abdominal segments 1, 2, 3, 4 and 5, a large horseshoe shaped marking, curve directed backward, two small transverse markings on segments 6 and 7. Eyes dark red. Antennæ longer than the body, pale except at joints which are black, 7th segment dusky. Antennæ on well-defined tubercles. Legs pale or reddish to tips of tibiæ which are black. Nectaries pale to black rings which are more or less conspicuous. Tail conical, pale. Under side of body greenish yellow except head which is pale.

The winged form has not been observed.

Hab. Oahu, Tantalus (1500) (D. T. F.); on *Physalis peruviana* in the cup of the inflated calyx.

Myzus *Passerini.*

Antennæ nearly as long as the body, on frontal tubercles which are gibbous on inner side. First antennal segment also gibbous. Wings moderately long, venation normal. Nectaries moderately long, cylindrical. Tail moderately long.

There are two species of this genus in Hawaii, to be distinguished as follows:

1. Body of both apterous and winged forms wholly black, antennæ not as long as the body.......... *M. citricidus*
   Body of apterous female yellowish green, of winged female generally green, only head, part of thorax and abdominal markings black, antennæ longer than the body.................................... *M. persicae*

Myzus citricidus Kirkaldy.

M. citricidus Kirkaldy. Proc. Haw. Ent. Soc., vol. 1, pt. 3, p. 100 (1907).

Apterous female. Form and color of *Myzus cerasi* (larva lighter). Eyes dark red. Antennæ black proximally and distally, segments 3, 4, and base of 5 whitish. Legs: most of femora, distal end of tibiæ and tarsi black, remaining portions whitish. Nectaries large, curved, wider at base than at apex, with inconspicuous rim, black. Tail large, conical, hairy, black. Small fleshy tubercle on thorax and succeeding segments. Antennæ nearly two-thirds as long as the body, on widely separated frontal tubercles. Length of body 2.15 mm.

Winged female. Form and general appearance of *Myzus*

cerasi. Black, shining, closely reticulate on tergites, abdomen above and below often widely dark brown medio-longitudinally. Eyes nearly black. Antennæ black, fourth and fifth segments white at base. Legs: femora black except at base, tibiæ whitish to tips, which with tarsi are black. Nectaries long, reaching tip of tail, slightly wider at base than at apex, not conspicuously rimmed, black at least basally. Tail conspicuous, about half the length of nectaries, ensiform, hairy, bent upward, black. Wings large, clear, cubitus and stigma whitish sordidly, veins pale fuscous, venation normal. Antennæ nearly as long as body, 7th segment longer than 3rd, 3rd and 4th subequal, each longer than 5th, 3rd segment with about 12 circular sensoria. A small tubercle on lateral margins of prothorax and others on lateral margins of abdomen. Antennæ on widely separated frontal tubercles. Length of body 1.75 mm. Length of antennæ 1.6 mm. Expanse of wings 5.25 mm.

Hab. Oahu, Honolulu (D. T. F.); Hawaii, Mana (G. W. K.); on *Citrus aurantium*.

Myzus persicae (Sulz.)

Aphis persicae Sulz., Kennzeichen Insecten, p. 105 (1761).

Aphis dianthi Schr., Fauna Boica II (1801).

Apterous female. General color yellowish green without black markings. Body long and tapering posteriorly. Eyes dark red. Antennæ and legs pale except at tips, which are dusky to black. Nectaries pale. Tail concolorous. Antennæ reaching base of nectaries, which are quite long. Tail long, ensiform. Length of body 1.8 mm.

Winged female. Head and thorax black or blackish. Abdomen green with dark (almost black) markings on dorsum of segments 4, 5 and 6, and sometimes extending to segments 3 and 7. Spots of similar color on lateral margins of segments 2, 3 and 4. Eyes dark red. Antennæ black. Legs pale, distal portions of femora, tibiæ and tarsi black. Nectaries long, thin, cylindrical (slight constriction at about middle), mouth conspicuously rimmed, black or blackish. Tail black, moderate, ensiform. Wings clear, iridescent, insertions yellow, stigma slightly dusky, veins thin, black, venation normal. Antennæ somewhat longer than the body, 7th segment slightly longer than the 3rd, 4th less but somewhat longer than 5th, 3rd seg-

ment with 10-12 circular sensoria in a single row. Length of body 1.75 mm. Length of antennæ 2 mm.

Hab. Oahu, Honolulu (D. T. F.); on *Brassica oleracea.*

PENTALONIA *Coquerel.*

Similar to *Aphis* but with remarkable venation. Third discoidal vein and its first branch (cubital) straight and anastomizing with a deformed stigmal vein, so that there appears, 1st, an inferior nerve (3rd discoidal) extending to basal margin, 2nd, a superior nerve (cubital) which bifurcates, the inferior branch extending to the basal margin, the superior branch again bifurcating, its proximal member being simple, its distal member again bifurcating before the margin is reached: there are thus formed five apical cells with approximately straight boundaries.

Pentalonia nigronervosa Coq.

P. nigronervosa Coquerel. Ann. Soc. Ent. France, p. 279 (1859).

Apterous female. Mahogany brown and somewhat polished, the larvæ and pupæ usually paler. Eyes reddish. First and second antennal segments almost black, third pale brown, fourth and fifth pale to black tips, sixth and seventh almost black. Segment three without sensoria but four and five with the usual large sensoria near the tips. Legs normal, outer third of femora, tip of tibiæ and tarsi black. Median light area on head and thorax. Dorsum of abdomen in median elevated portion almost black. Length 1.4 mm.

Winged female. Darker than apterous, almost black, thoracic tubercles prominent and polished. Antennæ dusky, first and second segments black, third pale in basal portion. Legs as in apterous form. Nectaries of moderate length, incrassate, mouth flaring, with distinct rim, black. Tail short and inconspicuous, white. On each segment a transverse row of minute white hairs. Wings clear, veins strong and black, somewhat shaded, stigma grayish black. Venation abnormal, cubital vein two forked and distorted, the stigmatic vein uniting with the outer branch of the cubital so as to form a distinct closed cubital cell contiguous to the stigmal cell. Hind wings with

only one branching vein. Antennæ as long as the body, the first segment much the stoutest, frontal tubercles prominent and gibbous on inner apical angle, seventh segment much longer than 3rd, 3rd about as long as 4th and 5th together, 6th, 4th and 5th, and 1st and 2nd subequal in length. Third segment with about 8-9 sensoria, 4th with 6 sensoria, three of them near the middle of the segment, 3 near the distal end, 5th with 3 smaller circular sensoria, 5th and 6th with the usual large sensorium near apex. Length of body 1.8 mm. Expanse of wings 4.25 mm.

Hab. Oahu, Honolulu (D. T. F.); on cultivated banana (*Musa* spp.)

RHOPALOSIPHUM *Koch.*

Antennæ on frontal tubercles which are not distinctly approximate, about as long as or longer than the body. Nectaries larger in the middle than at either end or distinctly clavate, moderately long. Tail more or less small and inconspicuous, sometimes conical.

Rhopalosiphum violae Perg.

R. violae Pergande. Can. Ent. vol. 32, p. 29 (1900).

"Apterous females dark cherry-brown and polished, the larvæ and pupæ generally somewhat paler. Eyes dark brown, third joint of antennæ more or less distinctly of a paler color than the body, the remaining joints black. Legs purplish, the femora darkest towards the end and the apex of the tibiæ and the tarsi black. Nectaries purplish. Head and thorax of the pupæ generally paler than the rest of the body.

"Winged females also dark cherry-brown or purplish-brown, the antennæ, thoracic lobes, terminal two-thirds or more of femora, apex of tibiæ and tarsi black; rest of the legs of a dull yellowish colour, with a tinge of purple. Nectaries and tail dusky. Wings clear, the veins strong and black and conspicuously shaded; stigma black; stigmal vein short and strongly curved. Antennæ of all, very long and slender, reaching considerably beyond the end of the body; joint 6 with its spur is much longer than the 3rd, joints 4 and 5 are subequal in length, and each of them somewhat longer than the 3rd; there are numerous sensorial tubercles on joint 3 and a few on joint 4,

while all of them are sharply serrate. The first joint is very much the stoutest, and bulging out strongly about the middle at the inner side; frontal tubercles prominent and gibbous at the inner apical angle. Legs long and slender. Nectaries clavate, reaching to the tip of the abdomen. Tail short and inconspicuous. Length of winged and apterous females about 1.6 mm. Expanse of wings about 5 mm."

I have copied Pergande's description of the species (supra) as my material was in such poor condition as to make it impossible to write an adequate description from it.

Hab. Oahu, Tantalus (1500-2000) (D. T. F.); on cultivated violets. I presume it was the same species that Mr. Kirkaldy observed at Puuopelu on Hawaii.

Toxoptera *Koch.*

Antennæ on no frontal tubercles, or on very inconspicuous ones, not approximate, sometimes as long as, usually a little shorter than the body. Legs moderate. Nectaries moderate, not as long as the breadth of the segment in which they arise. Tail conical. Cubital vein only once forked.

There are two species of this genus found in Hawaii, to be distinguished as follows:

1. General color of winged and wingless female black .... *T. aurantiae*
   General color of winged female green, wingless female brownish yellow .... *T. caricis*

Toxoptera aurantiae Koch.

T. aurantiae Koch. Pflanzenl., p. 254 (1854-7).

Apterous female. Dull black with sometimes a brownish tinge on head (the larvæ somewhat pruinose). Eyes nearly black. Antennæ nearly as long as body, black, 1st and 2nd segments black, 3rd, 4th, and 5th white with black at apex, 6th mostly black, 7th white with black tip. Legs fairly stout, front femora mostly brownish, black at tips, middle and hind femora mostly black, brownish at base, tibiæ pale dusky with black tips, tarsi black. Nectaries short, cylindrical, wider at base than at apex, mouth inconspicuously rimmed, entirely black. Tail small, black, conical and bent upward, beset with hairs. Length of body 1.52 mm.

Winged female. Somewhat smaller than apterous, black, abdomen on sides and backward from nectaries brown, a pair of tubercles on each side of thorax pale. Antennæ a little longer than the body, 1st and 2nd segments black, 3rd, 4th and 5th white with black apex, 6th mostly black, 7th white with black tip. Legs fairly stout, front femora brownish at base, black at apex, middle and hind femora black, tibiæ brown with black tip, tarsi black. Nectaries short, cylindrical, wider at base than at apex, entirely black. Tail conical, rather thick, black, beset with hairs. Wings clear, insertions yellowish, veins brownish, stigma long, narrow, black, venation normal, stigmatic vein extending from apex of stigma and much curved. Antennæ not approximate and hardly on frontal tubercles, 7th segment longer than 3rd, 4th and 5th subequal, 3rd with 8 large circular sensoria, smaller sensoria on 4th and 5th, on each of

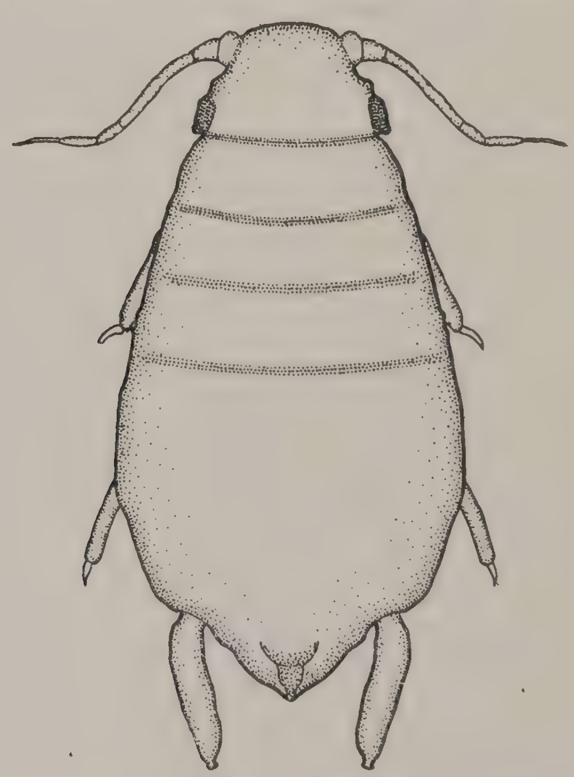

FIG. 3.—*Toxoptera caricis*, wingless viviparous female, enlarged, (original).

which there is the usual single large sensorium. Length of body 1.16 mm. Expanse of wings 4.3 mm.

Hab. Oahu, Tantalus (2000), Niu (2000), Palolo (1500) (O. H. S., D. T. F.); on *Pelea, Straussia, Coffea.*

Toxoptera caricis n. sp.

Apterous female. Brownish yellow, lighter at the margins. Eyes dark red. Antennæ, legs and nectaries concolorous. Tail

darker. Rostrum with black tip. The body is broadly oval and flat, so that the legs seem close together. Integument hard. Antennæ short, less than half the length of the body, third segment the longest, 7th which is filiform and about one-third of 3rd nearly equal to 4th, 5th still smaller, less than one-half of 4th. Nectaries very large, extending half their length beyond tail; base and apex much constricted, the mouth rimmed; otherwise broad for their length. Tail small, ensiform. Length of body 1.44 mm.

Pupa similar to apterous female with the exception of pale wing cases.

Winged female. Green, head and thorax dark olive brown, prothorax greenish yellow with dark olive-brown band. Abdomen light green. There are usually a few small dark-red spots toward the base in center on dorsum. Eyes dark red. Antennæ dark brownish black. Legs pale to tips of tibiæ, which with tarsi are black. Nectaries moderate, reaching beyond tip of body, pale to green, clavate and much bent. Tail short, conical and black. Wings ample, clear, iridescent, insertions light yellow, stigma long, thin, dusky, veins black. Cubital vein only once forked. Antennæ about two-thirds length of body, reaching base of nectaries, 3rd segment the longest, 7th less than 3rd but longer than either 4th, 5th or 6th, which are subequal, 3rd, 4th and 5th segments cicatrized with many circular sensoria, one large circular sensorium at tip of 6th. Length of body 1.5 mm. Length of antennæ .9 mm. Expanse of wings 4.65 mm.

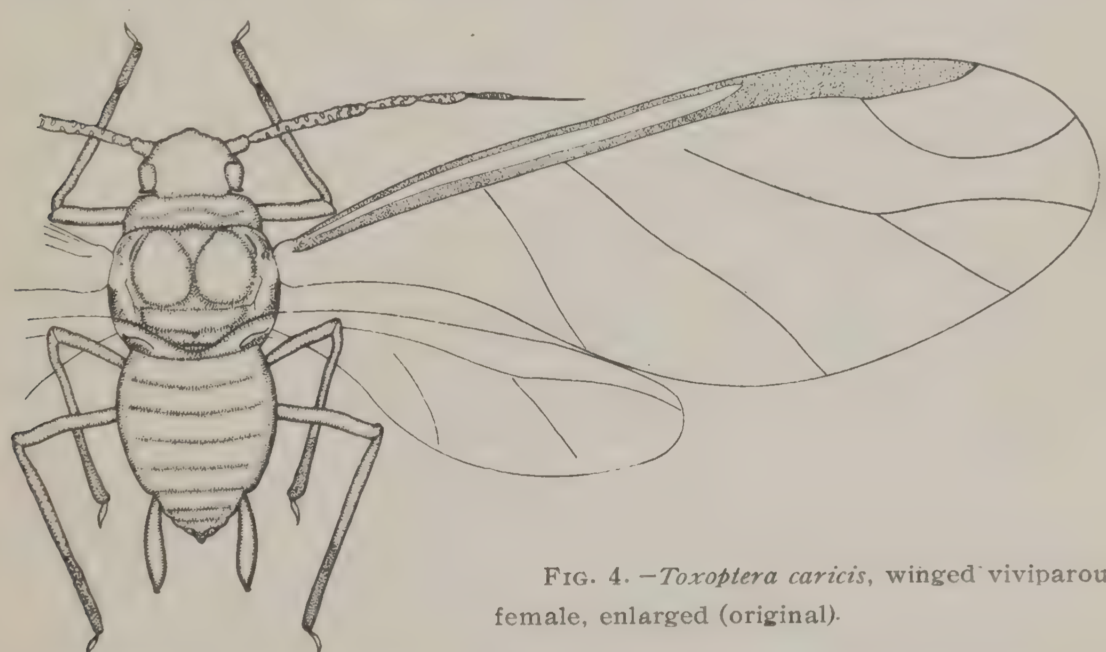

FIG. 4.—*Toxoptera caricis*, winged viviparous female, enlarged (original).

Hab. Oahu, Pauoa V. (1500-2000) (D. T. F.): on a species of *Carex*.

APHIS *Linnaeus.*

Antennæ on no frontal tubercle, or on very inconspicuous ones, usually shorter than the body. Wings rather short and broad, deflexed in repose, venation typical. Legs moderately long. Abdomen short and broad, rounded or obtuse behind. Nectaries moderately long, cylindrical or slightly incrassate, sometimes small. Style usually short, more or less thick, conical.

There are seven species of this genus found in Hawaii, to be distinguished as follows:

1. Nectaries conspicuously short, about twice as long as wide .... *A. sacchari*
   Nectaries not so short, much more than twice as long as wide 2
2. Third antennal segment with not more than 12 large circular sensoria—from 3 to 12........ 3
   Third antennal segment with more than 12 large circular sensoria—14 to 20........ 5
3. General color black, apterous female with white waxy secretion on dorsum........ *A. bambusae*
   General color green or mixed with green, apterous females without waxy secretion........ 4
4. General color green, sometimes with reddish tinge, dorsum much marked with black, 3rd antennal segment with 10-12 circular sensoria........ *A. swezeyi*
   General color dark green to almost black, sometimes mixed with orange yellow, dorsum with lateral black spots, 3rd antennal segment with 3-8 circular sensoria........ *A. gossypii*
5. Third antennal segment conspicuously cicatrized, wider than following segments, apterous female and larvæ covered with a mealy or woolly substance .... *A. brassicae*
   Third antennal segment not conspicuously wider than the following segments nor cicatrized, apterous female and larvæ not covered with a woolly substance 6
6. General color of apterous females dark green........ *A. maidis*
   General color of apterous females yellowish green .... *A. myosotidis*

Aphis sacchari Zehntner.

A. sacchari Zehntner. Arch. Java Suiker. V, p. 551 (1897) and IX, p. 673 (1901).

Apterous female. Greenish (larvæ paler). Eyes dark red. Antennæ slightly more than half the length of the body, black distally, 1st to 5th segments pale, 6th and 7th black. Legs pale to tarsi, which are black. Nectaries conspicuously short, black. Tail moderately long, much wider at base than at apex, which is conical, black. Length of body 1.3 mm.

Winged female. Head, thorax and transverse band on neck black, prothorax and abdomen light to dusky green. Eyes dark red. Antennæ black, except base of third segment, which is green. Legs light to tarsi, which are black. Mid and hind femora sometimes dusky distally. Nectaries conspicuously small, black, wider at base than at apex, which has a distinct rim. Tail small, conical, black and hairy. Wings clear, insertions yellowish. Stigma dusky, veins black, venation normal. Antennæ two-thirds as long as body, 7th segment considerably longer than 3rd, 5th less but a little longer than the 4th. Third segment with about 7 circular sensoria. Length of body 1.6 mm. Length of antennæ 1.08 mm.

Hab. Oahu, Honolulu, and probably throughout islands where sugar cane is grown (O. H. S., G. W. K.); on sugar cane (*Saccharum officinarum*).

Aphis bambusae n. sp.

Apterous female. Black beneath flocculent white waxy secretion. Eyes reddish black. Antennæ generally a dull white, segments 1, 2, 6, and 7 towards tip black. Legs pale to tarsus which is black. Coxa and trochanter black, distal end of femur and proximal end of tibia slightly blackish. Nectaries short, not reaching the end of the body by twice their length, black. Tail short, conical, dusky with four pairs of hairs directed backward. Two lateral rows of black spots dorsally on abdomen converging at point opposite base of nectaries. Two lateral rows of black spots on venter which do not converge. Antennæ about as long as the body on slight erect tubercles. The waxy secretion is apparently absent across the thoracic region and around the base of the nectaries. Length 1.07 mm.

Winged female. Much smaller than the apterous form.

Waxy secretion absent. Color black. Eyes black. Antennæ dusky to black, the two basal segments black. Legs black to tip of the femur, tibia pale except extreme base and tip which are black, tarsus blackish. Nectaries small, slightly longer than tail, black. Tail small, dusky, with a pair of hairs which are directed backward. Wings extending greatly beyond body, clear, iridescent, stigma dusky, veins black, venation normal, antennæ about one-fourth longer than the body. Seventh segment the longest, about twice as long as 3, 3, 4 and 5 sub-

FIG. 5.—*Aphis bambusae*, wingless viviparous female, enlarged, (original).

equal. Third segment with 8 circular sensoria in a straight line and tubercular, 4th segment with 6 and also tubercular, 5th segment with 7 but only slightly tubercular, 1st segment broad. Length of body .8-1 mm. Length of antennæ 1.17-1.25 mm. Expanse of wings 3.4 mm.

Hab. Oahu, Honolulu (D. B. K., D. T. F.); on a bamboo (*Phyllostachys?*).

Aphis swezeyi n. sp.

Apterous females. General color green, mottled with black, sometimes lightly covered with mealy bloom. Larvæ lighter

green without black markings. Eyes dark red. Antennæ about half the length of the body, dusky to black, bases of segments 3 and 4 dirty white. Legs long, black, base of femora and tibiæ except tip white. Head black, thoracic segments with broad, black transverse bands and lateral spots. Abdominal segments to one in front of nectaries with large black lateral spots and dorsal central markings which decrease in size caudad. Segment in front of nectaries has wide, thin, transverse, black marking (broadly interrupted), segment with nectaries has some indistinct central dorsal markings, the two following seg-

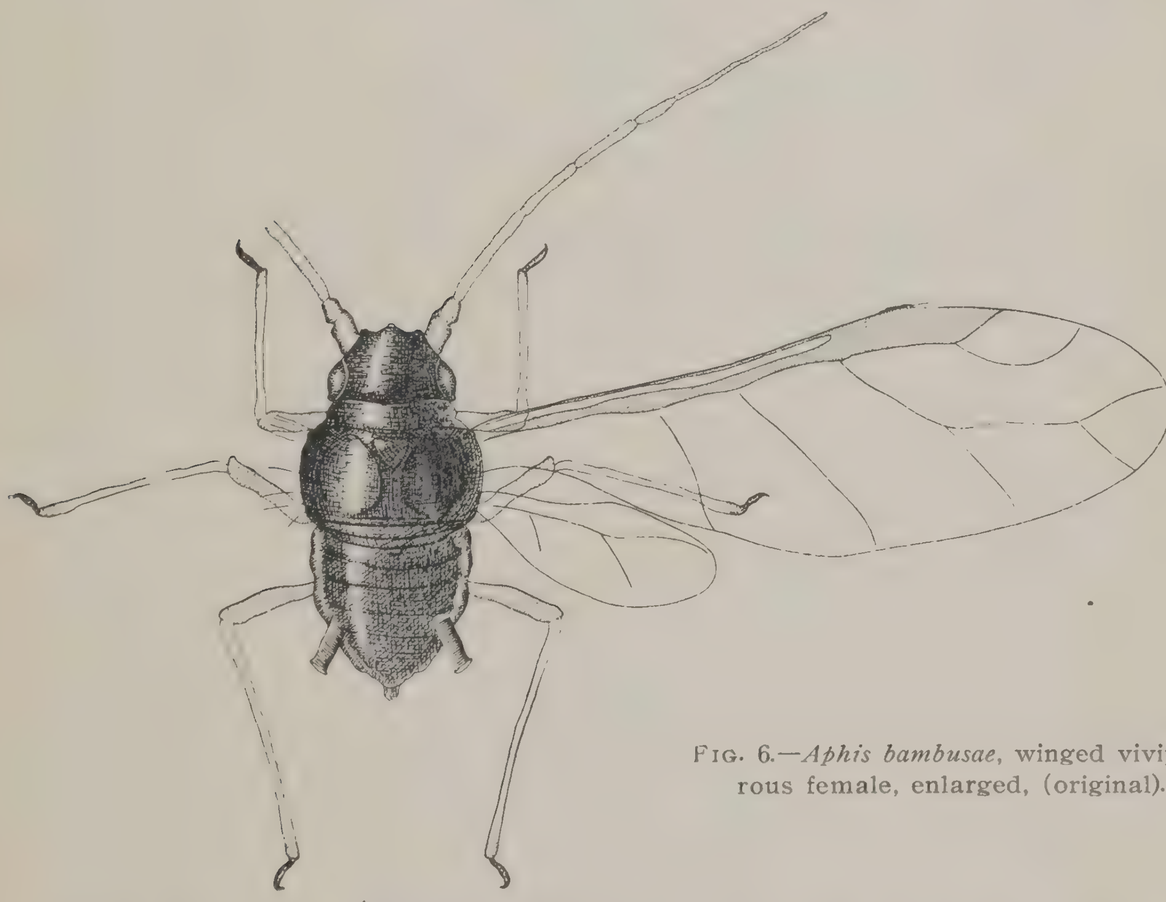

FIG. 6.—*Aphis bambusae*, winged viviparous female, enlarged, (original).

ments each a transverse black band. There are six large lateral spots in front of nectaries and a smaller spot just behind them. On the ventral surface, which is green, obscured by whitish bloom, there is a lateral row of smaller markings from the 1st segment caudad. Thoracic and abdominal tubercles well marked. Nectaries short, not reaching tip of tail, cylindrical, more or less imbricated, with distinct rim, black. Tail short, conical, tip black. Length 1.62 mm.

Winged female. Head black, thorax shining black, prothorax with transverse black band, on either side of which it is green or reddish, abdomen dull green with a reddish tinge.

There are three large lateral black spots on each side, with corresponding thin transverse markings extending medad in front of nectaries; behind nectaries is one lateral black spot on each side and the following two segments have each a transverse black band. Eyes dark red. Antennæ black except base of third segment. Legs dusky to black except base of femora and tibiæ, only the point of which is black. Nectaries

FIG. 7,—*Aphis swezeyi*, wingless viviparous female, enlarged, (original).

very short, not reaching tip of tail by much more than their length, black, conspicuously rimmed. Tail moderately long, black. Wings clear, insertions reddish, cubitus, stigma and veins dusky. Venation usually normal, sometimes second fork of cubitus absent, stigmatic vein much curved. Antennæ a little more than one-half the length of the body, third segment longest, nearly a third longer than 7th, 4th considerably less than 7th but longer than 5th, 6th smallest; third segment with

10-12 circular sensoria, one on the 4th, the 5th and the 6th. Length of body 1.61 mm. Length of antennæ .9 mm.

Hab. Oahu, Halawa (O. H. S., D. T. F.); on *Gnaphalium*.

Aphis gossypii Glover.

A. gossypii Glover. Pat. Office Report 1854, p. 62.

A. gossypii Glover. Pergande, Ins. Life 7, p. 309-315 (1895).

Apterous female. Very variable in color, light lemon yellow to dark greenish with obscure markings and even dull and polished black,[1] sometimes pulverulent with a bluish tinge. Eyes red to deep black. Antennal segments 1, 2, 6, 7 and tip of 5 dusky to black, remainder pale. Legs pale to tips of tibiæ, which with tarsi are black, femora sometimes blackish distally. Nectaries short, black. Tail short, conical, concolorous with dusky tip and bearing two backward curving hairs. Antennæ about half as long as body or slightly longer. Prominent conical and fleshy tubercles on either side of prothorax and behind nectaries and four smaller tubercles on each side of abdomen in front of nectaries. Length of body 1.2-1.8 mm.

Winged female. Head, thorax and transverse band on neck black, thoracic tubercles conspicuous and shining, neck and prothorax green, sometimes very dark, abdomen orange yellow in front, green behind, or blackish with green markings. When light, four lateral black spots can be distinguished, the last at base of nectaries. Eyes dark red to nearly black. Antennal segments 1 and 2 black, 3 mostly black, white at base, 4, 5 and 6 white basally, black apically, 7 black. Legs pale to tips of

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[1] Note. It is difficult to decide whether there is one or two species on this long list of food plants. The wide differences in size and color led me to believe at first that there were two distinct species, but a more careful examination of a great mass of material shows no distinguishing character that is constant for any part of it. I am inclined to believe, however, that the aphid found on *Medicago denticulata*, *Phaseolus lunatus* and *Portulaca oleracea* is different from *A. gossypii*, which as seen on cotton is never a polished black. Mature apterous individuals of the aphid on the above-mentioned plants have large, swollen abdomens, which are polished black in color with surface reticulation. The alate forms are also sometimes somewhat polished black, obscuring a dark green beneath. It is interesting to note in this connection that Dr. Filippo Silvestri in his report on a recent visit to the Hawaiian Islands (Bol. Quind. Soc. Agr. Ital., 14 (1909), no. 8, p. 344) states that he observed *Aphis papaveris* on beans. The species may be *A. papaveris* or *A. medicaginis*, but it does not answer closely the description of either of these species, and it will be necessary to make more extended observations to settle the matter.

tibiæ, which with tarsi are black, hind and sometimes mid femora black. Nectaries black, moderately long, cylindrical, wider at base than at apex, mouth not conspicuously rimmed. Tail concolorous, pale or dusky, moderately long, conical. Wings clear, iridescent, insertions and cubitus pale yellow,

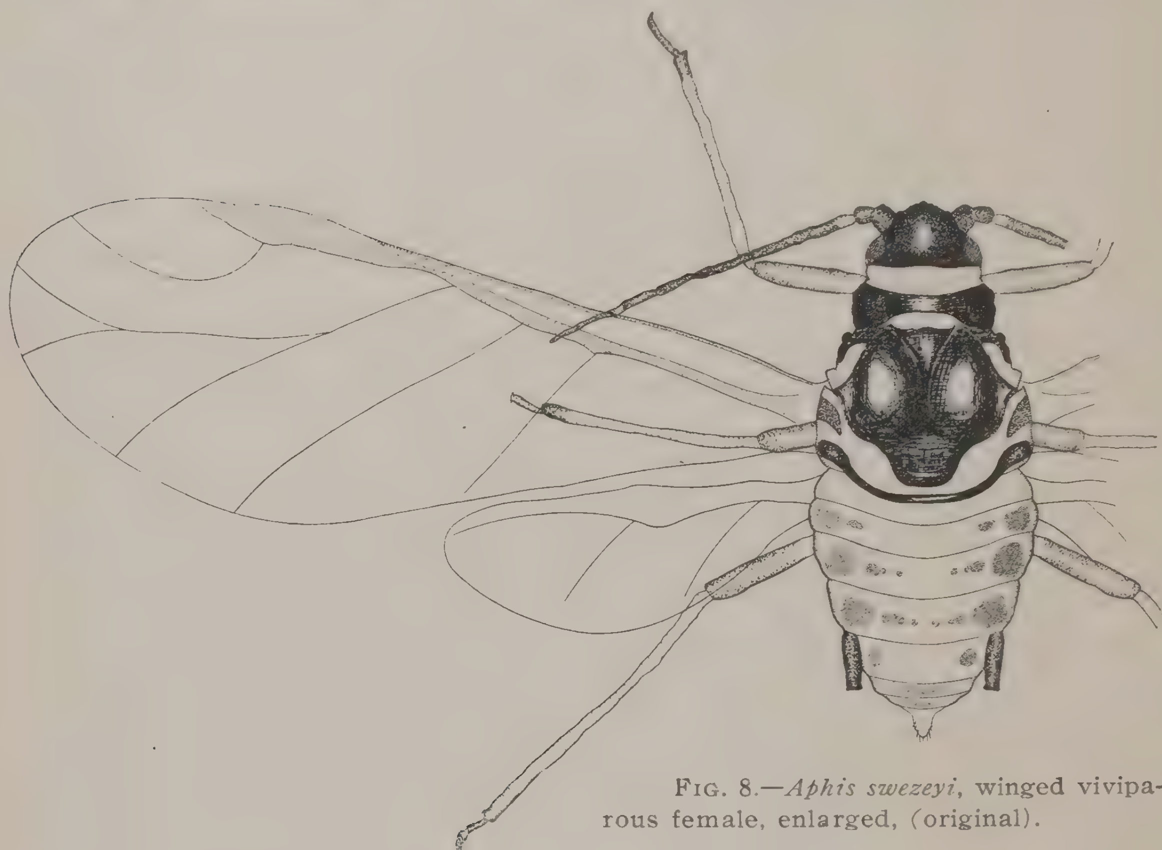

FIG. 8.—*Aphis swezeyi*, winged viviparous female, enlarged, (original).

stigma yellow to dusky, veins brown, stigmatic vein much curved, venation normal. Antennæ one-half to two-thirds as long as body, in latter case nearly or quite reaching base of nectaries, 7th segment a little longer than 3, 4th and 5th subequal and each less than 3. Third segment with 4-8 large circular sensoria. Length of body 1.2 mm.-1.8 mm. Length of antennæ about 1 mm.

Hab. Oahu, Honolulu, Wahiawa, Waipahu mauka, Kunia, Tantalus (D. T. F.); on *Gossypium, Cucumis, Arum esculentum, Hibiscus rosasinensis, Medicago denticulata, Phaseolus lunatus, Portulaca oleracea, Cuphea, Bidens.*

Aphis brassicae Linn.

A. brassicae Linn. Syst. Nat. 1, 2, p. 734 (1735).
A. brassicae Linn. Fab., Ent. Syst. IV, p. 218.
A. brassicae Linn. Koch, Pflanzenl., 149-150 (1854-57).

Apterous female. Long oval, plentifully covered with a whitish mealy coat. When this is removed, the body beneath

is greenish with a row of 8 black spots a little removed from lateral margin. Eyes black. Antennæ green with black tips, shorter than body. Legs black. Nectaries very short, black. Tail small, black. Length of body 2 mm.

Winged female. Head, thoracic tubercles and transverse bar on neck black, prothorax and abdomen yellowish green with a row of fine punctures on each lateral margin and several obscure transverse dorsal markings. Eyes black. Antennæ dark brown to black. Legs dusky brown, pilose. Nectaries dark brown, black at tips, short. Tail small, conical, hairy, dark green or brown. Wings clear, with stout coarse veins and dark stigma. Antennæ about three-fourths as long as body, 3rd segment longer than 7th, 4th less than 7th but longer than 5th, third segment much cicatrized with more than 20 circular sensoria. From the fourth segment to the tip the antennæ are much more slender than in 3rd and basal segments. Length of body 2 mm. Length of antennæ 1.5 mm.

Hab. Oahu, Honolulu, Wahiawa (D. T. F.); on *Brassica oleracea.*

Aphis maidis Fitch.

A. maidis Fitch. N. Y. Rep't 1, 318 (1855).

Apterous female. General color dull dark green, the head, bases of nectaries and lateral and caudal margins generally dull black, body emarginate. Eyes dark red. Antennæ dusky to black proximally and distally, 3rd, 4th and 5th segments more or less pale, antennæ about half as long as the body. Legs black, femora sometimes pale. Nectaries black, not reaching tip of tail by more than their length. Tail black. Length of body 1.4 mm.

Winged female. Head, thorax and wide band across neck black, thoracic tubercles prominent. Neck on either side of band dark green. Abdomen light green, five lateral black spots, four before and one back of nectaries. Eyes dark red. Antennæ black. Legs black, front femora sometimes pale. Nectaries small, not reaching tip of tail by their length, sometimes incrassate, without conspicuous rim, black. Tail small, hairy, with subanal plate black. A distinct fleshy tubercle on lateral margins of penultimate abdominal segment. Wings clear, insertions and cubitus green, stigma dusky, veins thin and brown, venation normal. Antennæ more than half as long as the body,

3rd segment longer than 7th, 4th slightly longer than 5th but shorter than 7th. Third segment with 14 circular sensoria. Length of body 1.5 mm. Length of antennæ 1 mm.

Hab. Oahu, Honolulu, Kunia (D. T. F.); on sorghum (*Andropogon vulgare* var. *saccharatum*), corn (*Zea mays*).

Aphis myosotidis Koch.

A. myosotidis Koch. Pflanzenl., p. 57 (1854-57).

Apterous female. Yellowish green. Eyes dark red. Antennæ pale to sixth segment, 6th and 7th segments black. Legs pale to dusky, tarsi black. Nectaries concolorous, their tips black. Tail short, thick, hairy, concolorous. Body emarginated. Pupæ greenish.

Winged female. Head and thorax shining black, thoracic tubercles prominent, prothorax and neck green with a transverse darker band. Abdomen green with a darker area caudad of 2nd abdominal segment, which behind the nectaries takes the form of two transverse bands; four black spots on each lateral margin in front of nectaries. Antennæ black. Legs greenish to dusky, tips of femora, tibiæ, and tarsi black. Nectaries short, not reaching tip of tail, cylindrical and distinctly rimmed, black, base greenish. Tail short, thick, tip rounded, beset with hairs, concolorous, black beneath. Wings clear, insertions and cubitus pale greenish, stigma dusky, stigmatic vein much curved, nerves thin, black, venation normal. Antennæ short, not reaching base of nectaries, 7th segment a little longer than 3rd, 4th longer than 5th but only three-fourths the length of the 3rd, third segment with 15-16 large circular sensoria and a few smaller ones, the usual large circular sensorium at tip of fifth segment. Length of body 1.5 mm. Length of antennæ 1.1 mm.

Hab. Oahu, Tantalus (1000), Pauoa V. (1000) (D. T. F.); on *Erechtites* sp.?

Myzocallis *Passerini.*

Antennæ on no frontal tubercles, smooth, seventh segment longer than 6th, front wings with cubital vein twice forked, posterior wings with two oblique veins, nectaries tuberculiform or subobsolete.

Myzocallis kahawaluokalani Kirkaldy.

M. kahawaluokalani Kirkaldy. Proc. Haw. Ent. Soc., vol. 1, pt. 3, p. 101 (1907).

"Winged female. Pale yellowish, marked with pale brownish fuscous, principally as follows: Head dorsally with a mediolongitudinal line and a speck on each side of this, and lateral margins broadly, posterior margin narrowly; irregular, broad, submedian bands down the pronotum, lateral margins narrowly; a suboval, interiorly pale, sublateral spot on mesonotum, a goblet-shaped mark in the middle (the bowl anteriorly, the stem posteriorly), posterior margin broadly; a large irregular transverse spot near the base of abdomen; antennæ whitish, first two segments and apices of 3rd-5th pale brownish fuscous. Eyes bright pale vermeil. Abdomen dorsally and sublaterally with numerous fuscous-ringed tubercles which bear scarcely perceptible hairs, with two contiguous fuscous mammiform tubercles near the base in the middle, etc. Tegmina hyaline, very strongly particoloredly iridescent, subcostal ('costal') cell and stigma, veins and a V apically, pale fuscous. Legs pale, fore and middle femora with a fuscous annulation, hind femora broadly fuscous, apically, hind tibiæ fuscous basally; coxæ more or less fuscous. Honey-tubes short, pale, fuscous. Antennæ scarcely as long as the body, 6, 5, 30, 24, 22, 14, 12, the seventh not really separated from the sixth. Stigma rather long, longer than broad, curved. Length to apex of abdomen about 1.25 mill., to apex of flight organs about 2 mill.

"Hab. Oahu, Honolulu, on *Lagerstroemia indica,* an introduced plant (G. W. K.); also on other shrubs.

"Nymph. Pale yellow, eyes red as in adult. Head, nota and abdomen multituberculate dorsally and laterally, each tubercle with a black capitate bristle."

I have copied the original description of this species, (supra) as I have not seen specimens myself.

ERIOSOMA *Samouelle* (SCHIZONEURA *Hartig*).

Antennæ six-segmented, cubital vein only once forked. Posterior wings with two oblique veins, which usually originate close to each other, sometimes in contact.. The antennæ are short, those of the winged individuals extending beyond the end of the thorax, those of the apterous individuals usually

reach only to the end of the prothorax, third segment longest. No visible nectaries. Body usually rather broad, elliptical in the winged and broadly ovate in the apterous individuals. Colors are usually black, brown or reddish. Rostrum rather long and slender.

Eriosoma mali Samouelle.

Eriosoma mali Samouelle. Entom. Useful Companion, p. 232 (1819).

Schizoneura lanigera (Hausm.), Fitch, Cat. Homoptera N. Y. 67 (Lint. Rep. NY. Ent. 9, 411).

"Apterous individuals. About one-tenth of an inch long; reddish brown and covered above with a white, cottony secretion; antennæ short, and pale yellow; legs yellowish; knees brown; without honey-tubes, but with a circular cicatrix in place of each.

"Winged individuals. Antennæ shorter than the head and thorax, and varying in color from brown to black; head and thorax black, a brownish ring at the collar; the abdomen chocolate brown; legs brownish; wings hyaline with the veins and stigma deep brown; body enveloped in a white, cottony secretion. Serville and Amyot give the length of the apterous individuals as only eight-hundredths of an inch; they described the winged individuals as less and with the body almost naked."

I have copied the description given in Thomas,[1] as my material was in such poor condition as to make it impossible to write an adequate description from it.

Hab. Hawaii, Waiki (4500) (J. E. H.); on apple (*Pyrus malus*).

CERATAPHIS *Lichtenstein.*

Antennæ five segmented, the first two segments smooth, the remaining ones ringed. Third segment the longest, fourth and fifth nearly equal. Eyes large. Nectaries obsolete. Eyes of larva nearly obsolete. Head furnished with two minute characteristic frontal horns. Legs and antennæ very short and largely concealed by a disc of waxen filaments arising from peripheral glands.

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1 Thos. Rep't Ent. Ill. 8, p. 126 (1880).

Cerataphis lataniae (Boisd.)

C. lataniae Lichtenstein. Bull. France (6) 2, p. 16 (1882).

"Apterous female. Size of body 1.52x1.27 mm. Antennæ .25 mm. Coccus-like. Color rich brown, to the naked eye nearly black. Form oval or nearly circular. Edge of the body terminated by a string of minute transparent glands from which a clear disc of wax-like substance is secreted. This disc is striated and slightly fimbriated. It entirely surrounds the insect and hides the antennæ and legs below. In the spring of the year two or three pale folds occur across the dorsum of the insect.

"Antennæ very short; four jointed, the first and second joints nearly equal; the third the longest, and about double the length of the second. The fourth joint ends in a considerable nail, which, added to the rest, makes the whole joint nearly as long as the third. The front is furnished with two short projections or horns, the use of which is unknown. Eyes very minute; brown. Legs very short and normally formed like *Aphis;* ending with the usual tarsus and two claws, without the capitate hairs to be seen in coccus.

"Rostrum about one-fourth the length of the body. Cauda tuberculate, with two small papillæ. The under side is paler and mottled with brown.

"The young, born from the above insects, are much less coccus-like and do not greatly resemble their parents. After a short time they moult and become of a pale, ochreous green color. The wax glands soon after show themselves at the circumference of their bodies, and the growth of the disc is rapid and very interesting under the microscope.

"Winged female. Expanse of wings 4.06 mm. Size of body 1.77 mm. x 1.01 mm. Antennæ .88 mm. The imago apparently is very rare, for only three mutilated specimens are at present known. It has not yet been taken in England; but I have been able to make the above measurements from a specimen mounted by M. Richter of Montpelier.

"General color yellow. Antennæ with five articulations: the last three joints are much ringed. Vertex flat and without the horns seen in the larva. Eyes large; stemmata obvious. Wings folded flat on the back. Cubital vein is once forked, and it does not reach to the cubitus. First and second oblique veins unite

just before they touch the cubitus. Rostrum reaches to the second coxæ. Legs short, tarsi with two claws.

"The general appearance of the larva is so coccus-like that the venation shown by the imago is a little unexpected."

I have copied from Buckton [1] as the three or four specimens in my collection could not be used to frame an adequate description.

Hab. Oahu, Honolulu (G. W. K., D. L. VD.); on fan palm (*Pritchardia*).

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[1] Buckton. Monograph British Aphidae, vol. IV, p. 198.

REPORT OF THE HORTICULTURIST

By J. E. Higgins.

FRUIT-MARKETING INVESTIGATIONS.

The chief work in horticulture, during the first part of the year was a continuation of fruit-marketing investigations. Attention was given entirely to pineapples and the results of the work were reported in Press Bulletin No. 22.

PROPAGATION INVESTIGATIONS.

Citrus Fruits.

Considerable time has been given to studies in the propagation of citrus. Much difficulty has been experienced by those who have attempted to bud the citrus in Hawaii, and many failures have been reported. Information of similiar failures, even in the work of experienced propagators, has reached us from the Philippines. A careful study was therefore made of prevailing conditions and the difficulties to be overcome. The methods of budding used were those common in citrus culture and known as "shield budding," with a "T" shaped incision; with an inverted "T" and with right-angled and curved incisions. The two latter were used only with angular budwood and the curved incision was adopted only in old bark. While reasonable success can be expected from any of these, it is recommended that those who have difficulty in budding should adopt the ordinary method with the inverted "T." This is described in Bulletin No. 9 of this station, and in all works relating to citrus propagation. The tying may be done with raffia or strips of cotton which have been dipped in melted wax. If the latter are used, they should be held tightly in place by twisting together the ends. These experiments have added nothing new to the knowledge of methods of budding, but have discovered the causes which are believed to be chiefly responsible for the numerous failures reported, and have also afforded opportunities for the testing of remedies, thus point-

ing the way to success. The chief causes of failure are poor bud-wood, lack of vigor in the stocks, and insect attack.

Insects are frequently the sole cause, and the others, only subsidiary; but whatever may be the reason for the lack of vigor, whether it be infertility of soil, insufficiency of moisture, insects, or diseases, it must be removed and a vigorous, healthy condition restored before budding can be successful. Only when there is a comparatively rapid multiplication of cells, can the bud-shields and the stock unite. The bud-wood should be well matured and from a healthy growth. If selected before the most active growth begins, in the spring, it can be preserved in sphagnum moss until wanted. The moss,after being soaked in water, should be wrung out as dry as possible. It will then retain sufficient moisture to prevent the withering of the bud-wood, but will not induce decay. Spread out a thin layer of this moss on a sheet of heavy wrapping paper, place the bud sticks on it and roll up the package. It will be necessary to open the package every two or three weeks and again dip the moss in water. Bud-wood has been kept in excellent condition in spagnum moss at this station for several months.

Insects are the most prolific source of trouble in budding citrus in Hawaii. The work of testing methods of control has been carried on in cooperation with the entomological division of the station. Several species of insects have been very prevalent during the year and have thus afforded good opportunity for studying means of control. Chief among these insects are the following:

Scale insects and mealy-bugs.—A mealy-bug (*Pseudococcus filamentosus*) is prevalent on all species of citrus trees in Hawaii. Not only does it greatly reduce the vitality of the tree, but if an incision is made in the bark of an infested tree, as is done in budding, it is quickly occupied by a new colony of mealy-bugs. These rapidly multiply, cover the bud and destroy it. The young are so minute and so near the color of the bark that the new infestation may not be observed until the colony is well established.

The purple scale and the Florida red scale are also very destructive to citrus trees and if not checked, render budding extremely difficult.

Remedies. The most effective remedy for such scales and mealy-bugs has been fumigation with hydrocyanic acid gas.

In most instances, one treament has been sufficient to rid the tree of the pests (see remarks below, relating to fumigation). Ladybirds, (Coccinellidæ) do much to hold some scale insects in check, but up to the present time, at this station, they have not proved sufficient for the task of holding in control the three species mentioned above to a degree sufficient for the purposes of budding.

Climbing cutworms have been very destructive to many crops on Oahu during the year, and were numerous in the citrus orchards where most of the budding was performed. The damage consists in the devouring of the bark of the bud or budshield, or if this has escaped until the new shoot appears, the latter is girdled or completely cut off. It has not been found difficult to destroy these insects by placing poisoned bran on the surface of the soil about the trees. A small amount is sufficient and the remedy is effective and inexpensive. It consists in the following:—Paris green, ¼ pound, wheat bran, 10 pounds, sugar (brown), 1 pound, water, sufficient to moisten. Mix the Paris green, bran and sugar while dry and add a little water but not enough to prevent crumbling.

Archips postvittanus.—This insect in the larval stage, does much injury by folding the new leaves and also by eating the foliage. The remedy applied has been arsenate of lead in the proportion of 5 pounds to 100 gallons of water.

Aphids.—These are familiar to all as small greyish-black insects, some being winged and inhabiting the youngest growth in such numbers as frequently to cover the branch. They are usually overtaken by their natural enemies, but it sometimes becomes necessary to apply weak solutions of whale oil soap to assist the shoot while young.

Citrus Stocks.

The citrus stocks being tested run in parallel rows and consist of the following:—Rough lemon, sweet orange, shaddocks and seedlings from California grown pomelos. This is about the order also in which they stand at the station in their vigor of growth and their ability to produce growth in the inserted buds. They are so arranged in the orchard that each important variety of orange, lemon, or pomelo is budded on each of these stocks. Plate I shows six months' growth of

a Bahia or Washington Navel orange on a common sweet orange stock.

Seasons for budding.—The budding of the citrus trees was done during January, February, March, and April and appeared to be equally successful in all of these months if the individual trees were in active growth. How much longer it could have been continued, we do not know. The buds set early in the year are, of course, ahead in point of growth.

MANGO PROPAGATION.

The system in vogue in mango propagation, known as "patch-budding," has been practiced for several years. It has been defective as a commercial system because it requires that both the bud-wood and the stock shall be in a condition of rapid growth when the work is being done, and further, because the operation cannot be performed with sufficient rapidity. It was, therefore, sought to devise a method of budding the mango which would be an improvement in these or other particulars. The device that has been adopted consists essentially in the application of shield-budding with the inverted "T", using well matured wood as in patch-budding, and cutting the "T" and the shield very long. The incision is usually made six or seven inches long and the shield, about three or four inches. By this method, budding can be performed when only the stock is in active growth and the work can be done much more rapidly. Full instructions, together with data relating to the histology of the bud-union, are described in Bul. No. 20.

Inarching.—This method of propagating the mango has been, to a large degree, supplanted by budding in the practice of this station. It has been found very useful, however, in dealing with valuable trees that have become pot-bound or otherwise stunted. Mango trees have been received by mail and by freight from long distances. It requires considerable time for these to recover and some have never made a satisfactory growth, even when planted in the orchard with the best of care. The plan has been adopted of inarching a branch of such trees to the trunk of a vigorous seedling, later cutting off the whole top just above the union. For this purpose, the pot is plunged in the soil at the root of the seedling. This aids in maintaining uniform moisture in the pot, and also in plac-

ing the graft low on the stock. On a well established seedling root-system a single branch thus inarched will often make more growth in six or seven months than a whole tree placed in the orchard on its stunted root-system, could make in a year or two. After a month or two, when the inarching process has become complete, the potted tree can be removed to the side of another seedling and a second branch may be grafted. This has been found to be the best use that can be made of new introductions of mangoes.

AVOCADO PROPAGATION.

Some preliminary work has been done in avocado budding to determine the most satisfactory methods and season for such operations.

RECORDS.

The system of records of plantings and of the life history of plants in the horticultural division has been evolved as the needs of the work demanded. The system at present consists of the following:—

1. Accession book.
2. Alphabetical card index.
3. Loose-leaf note books.
4. Maps of fields.
5. Photographs.

In the accession book, as now used, very little is recorded except the date, the name, and the number in its numerical order. This affords a ready reference from any label number. The card index is arranged alphabetically. Here are recorded all the data available at the time of planting, except when a large amount of detail is necessary. In most instances, the card has proved sufficient for the whole record from planting to the present date. In the more elaborate experiments, loose-leaf note books are used and indexed by subject referring also to the accession numbers.

During the year just closed, the four cultivated fields of the station, in which are most of the plantings of the horticultural division, have been carefully surveyed and mapped. The station is greatly obligated to the Survey Department of the Territory of Hawaii for cooperation in this work in the making

of the original surveys and outline maps. Mr. C. J. Hunn, assistant horticulturist, has located all plants and recorded on the maps their position and number. Plate II shows a general view of these four fields, designated as fields A, B, C, and D. Each of these fields is divided into sections running from south to north. The sections are determined either by natural boundaries or by the character of the more permanent plantings; and are designated by Roman numerals. Where necessary, these sections are cut into divisions running throughout the entire length of the section. These divisions are designated by Arabic numerals and are numbered from left to right, as are also the rows. Further subdivision has not been found necessary up to the present time, but can be adopted as required. To illustrate, the index card "*Mangifera indica,* No. 1942" indicates the location of this trees as "C. IV. R. 3. The tree can immediately be located in Field C, Section IV and Row 3. (see Plate III). This field being narrow, no divisions are used. A tree in Field B might be designated "B. II. 2, R. 1. It would be found in Section II, division 2, row 1.

A very convenient use is made of this mapping system in loose-leaf note book records. Certain sections are photographed and the print inserted where needed in the notes. For example in Field C, section IV (see Plate III), which includes the mango orchard, considerable work has been done in budding and inarching on certain trees. It adds much to the convenience and accurracy of records to have a map of this section in the note book.

This mapping has required much time and patient effort at the beginning, but will result in economy of time and in greater accurracy in the making and availability of all records.

DEVELOPMENT OF EXPERIMENTAL ORCHARDS.

There are being developed, for experimental use, citrus, mango, and avocado orchards and also miscellaneous collections of fruit plants. These are already being used for experimental purposes. In connection with the propagation studies a large part of the citrus orchard has been budded to the leading varieties of orange, lemon, pomelo, lime and other species.

The propagation work with mangoes has afforded a similar

opportunity to change part of the seedling plantings into an orchard of varieties of known or reputed merit..

The Use of Hydrocyanic Acid Gas in Orchards.

In cooperation with the entomological division, a test has been made of the adaptability of hydrocyanic acid gas to Hawaiian conditions and of the efficiency of this gas in destroying certain insects not common where fumigation methods have been most carefully worked out.

The remedy has been found so effective in destroying the mealy-bug on citrus trees, *Pseudococcus filamentosus;* and the avocado mealy-bug, *Pseudoccus nipae,* as well as the Florida red scale, and the purple scale which have long been held in check by this means in the citrus belt of the mainland, that it has been adopted in orchard treatment at the station to the exclusion of oil sprays whenever the work of the natural enemies available proves insufficient for the task. The *P. filamentosus* is the more difficult to kill, because of its very heavy covering of cotton-like filaments; but when fumigated while the trees have no new growth, even the eggs of this insect have been destroyed without injury to the foliage. It is necessary to remove a few inches of soil from the crown so as to expose to the gas, the insects on this part of the tree.

COVER CROPS.

The use of cover crops in the station orchards during the rainy season has become an established practice. Only the jack bean and cowpea of the clay type have been used during the year as cover crops since these proved best adapted to the purpose of any legumes tested in earlier trials. The cowpea is a rapidly maturing crop, furnishing a large amount of green manuring and remaining green as long as necessary for the average rainy season. If the wet weather should be prolonged, the cowpea might pass the stage of best growth for green manuring before it would be safe to open the ground to the washing of rains. The seeds were planted in Field C on January 2 and 4, the rainy season having apparently begun. The first flowering was observed March 17, and the crop was plowed under April 20 and 21.

The cowpea is very subject to the attacks of a species of aphid (*Aphis medicaginis*) and if the natural enemies of the latter are not present, the whole crop may be destroyed. A severe attack of aphids occurred in the plantings referred to above, and for several weeks the plants made practically no progress. Later, six or seven species of ladybirds (Coccinellidæ), multiplied rapidly and completely overcame the aphids, so that early in March the plants were again in vigorous growth and very rapidly covered the ground. These experiences give rise to two practical suggestions. If cowpeas are to be used as a cover crop during the seasons when aphids are most abundant, the grower should see that colonies of the beneficial insects are at hand. Cowpeas may be used as a means of multiplying ladybirds of the six or seven commonest species in Hawaii, if the plantings are not in the neighborhood of valuable trees or plants which are also subject to attacks of aphids.

Jack beans do not come to maturity so rapidly as cowpeas and may be used where it is desired to keep the ground covered longer. They are also less subject to the attacks of aphids.

The pigeon pea (*Cajanus indicus*), has proved a valuable leguminous plant, but its growth is so tall and also so woody that it becomes difficult to cover.

A number of other legumes are being tested in plats and some of the more promising of these may be tried under orchard conditions.

WIND-BREAKS FOR ORCHARDS.

A wind-break has been planted about Fields B and C. This consists of a row of *Eucalyptus robusta* on the outside, and a row of Monterey cypress (*Cupressus macrocarpa*) within. The trees in each row are about eight feet apart and the Monterey cypress stand opposite the open space between the Eucalyptus. By these two species, the Eucalyptus running rapidly upwards, and the cypress being of dense growth near the ground, it is expected to provide an effective wind-break.

VEGETABLES AND SMALL FRUITS.

Mr. C. J. Hunn, assistant horticulturist, has under way a number of experiments with vegetables, muskmelons, and the

roselle. A test of quite a large number of varieties of tomatoes is being made with a view to determining, among other things, their varying degrees of resistence to the melon fly. An attempt is being made to grow muskmelons under a cheese-cloth covering to protect them from the melon fly.

A trial is being made of the "Mercedes" type of sweet potato in comparison with a few local varieties. It is this type which is being almost universally found in the Pacific Coast markets, which Hawaii should supply during the spring and early summer months. It may prove best to introduce our own varieties in these markets.

The culture of the roselle has been continued and some tests have been made in drying this fruit. Mr. Hunn submits the following data on the subject:

"A number of queries concerning the advisability of drying the roselle, thus making it less bulky for, and less susceptible to decay during shipment, have come to the attention of the horticultural staff. Accordingly, a number of experiments were undertaken to ascertain the advisability of drying the roselle, dealing almost exclusively with the calyx of the plant, since this is the portion generally used in jam or jelly making.

"Three separate experiments were conducted in drying the roselle, the first two being with the Porto Rican strain, and the third, with the Victor variety. The first lot was picked November 24, 1908—36 weeks from sowing; the second lot, on December 8,—38 weeks from sowing; and the third, on December 8, 1908,—36 weeks from sowing. The first lot was placed out of doors for drying on November 26, 1908, and kept in the open as much as possible, being removed to a dry building at night, and at other times because of the frequent rains which are so prevalent at this time of the year, and which would seriously interfere with the ultimate results of drying. The fruits were placed in shallow slatted flats with cotton cheese cloth spread over the bottom to prevent loss through the slats. When sufficiently sun dried, the flats were stacked in a dry airy exposure to finish curing.

"The results of the drying experiments are as follows:—The portion eliminated before drying equals 32 per cent, leaving 68 per cent, which is the total weight of the calyces to be dried. The calyces in drying shrank to 8.8 per cent of the total

weight of the fresh fruit, or lost, in drying, moisture equal to 7.7 times its weight. Consequently, one pound of the dried calyces is equal to 8.7 pounds of the fresh calyces, or to 12.8 pounds of the fresh fruit.

"If fresh roselle sells at four cents per pound, in order to make an equal profit from the dried calyces, it should sell at about forty-five cents per pound, plus the cost of drying. In drying the roselle such items as severing the calyces and the seed pod by cutting, separating the calyces from the seed pod after cutting, boxes, the moving and the care of the fruit during drying and storage must also be considered. From figures obtained from companies who are interested in the production of jellies and preserves, we ascertain that they are not willing to pay such a price for the dried roselle and offer less than one-half.

"It is apparent that the rational and profitable method of marketing Hawaiian roselle is in the form of jams and jellies, manufactured here, thus avoiding the cost of drying. It is also probable that the fresh fruit will make a finer manufactured product than the dried article."

THE HORTICULTURAL STAFF.

The horticultural staff has been augmented by the appointment in June of Mr. Valentine Holt, a part of whose time is being devoted to horticultural work. Mr. Holt has collected and prepared an exhibit of a large number of fruits and other products now being shown at the Alaskan-Yukon-Pacific Exposition. He has begun work in the selecting and propagation of varieties of papayas with a view of systematic breeding.

MISCELLANEOUS NOTES.

The horticulturist again visited the deciduous orchards planted in recent years at the Parker Ranch on Hawaii and advised in matters of pruning and general care, also noting the progress of the orchards which give every promise of success.

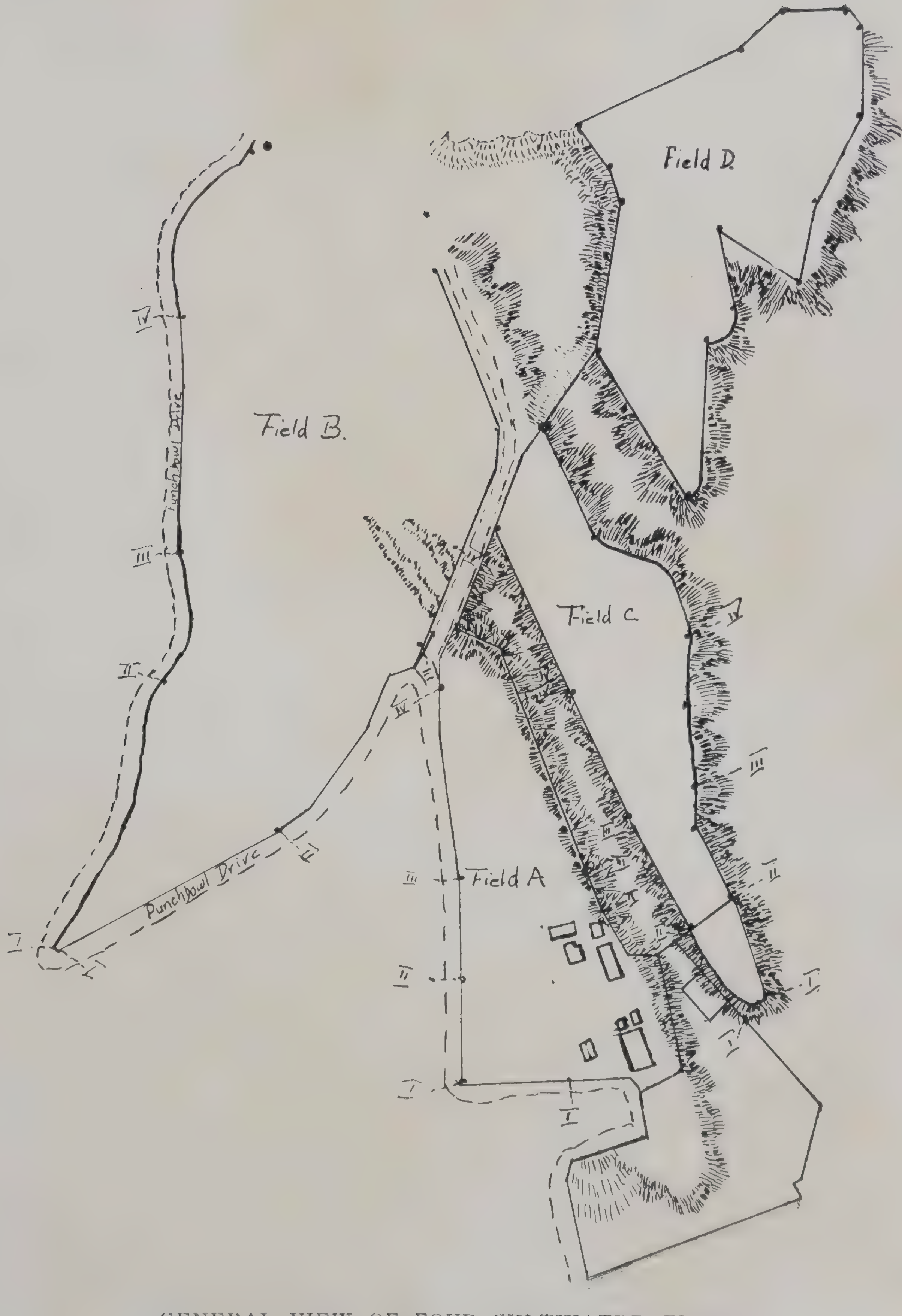
The three varieties of litchi, introduced in June, 1908, have made a good growth during the year. These varieties are No mi chi, Kwai mi and Hak ip.

Carissa arduina, S. P. I. No. 11,734. This South African

PLATE I

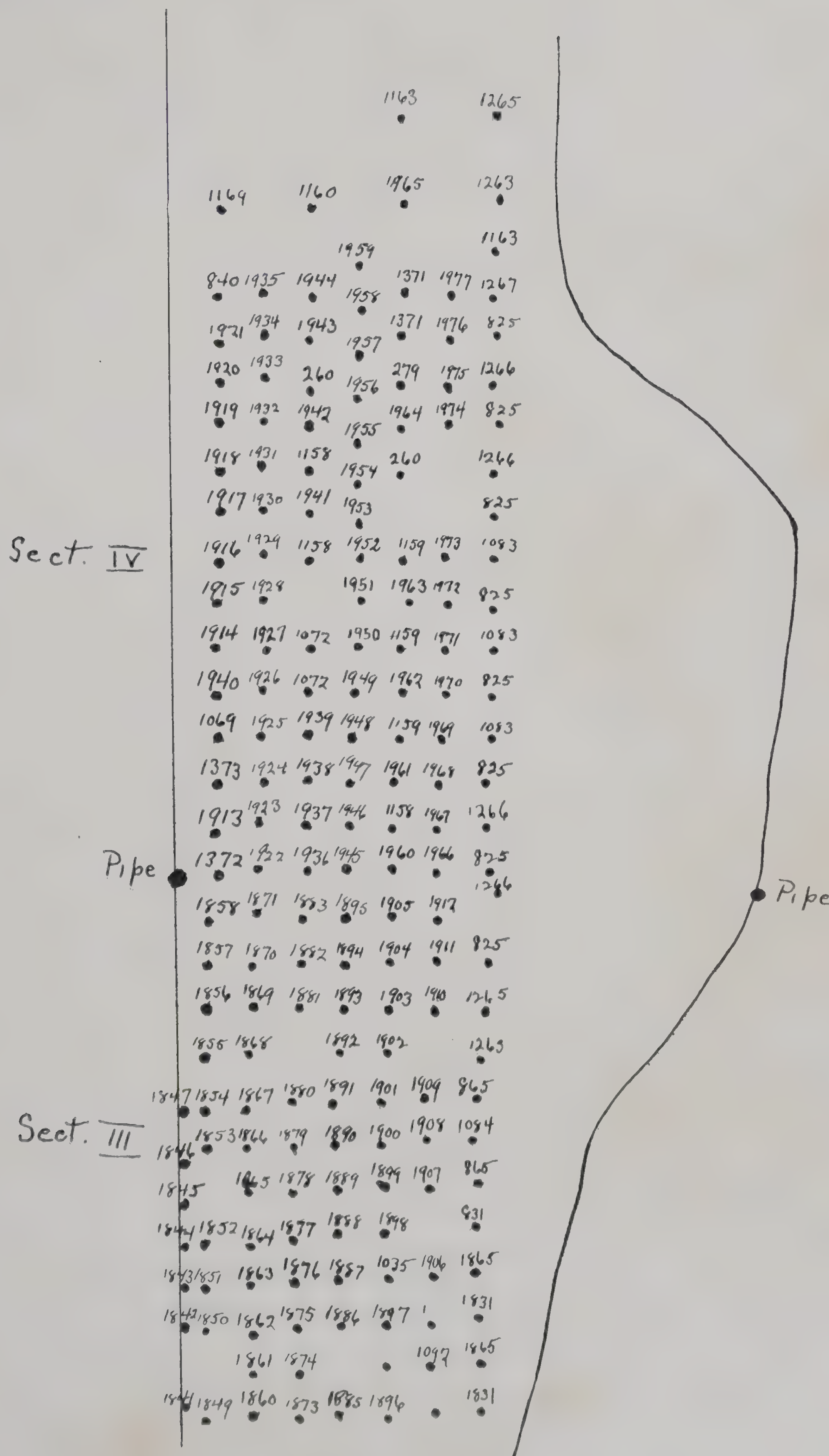
BAHIA NAVEL ORANGE ON COMMON SWEET ORANGE STOCK, 6 MONTHS' GROWTH FROM BUD.

PLATE II.



GENERAL VIEW OF FOUR CULTIVATED FIELDS.

PLATE III.



FIELD C, SHOWING LOCATION OF TREES.

fruit and hedge plant has fruited at the station in the past few months. It has made a strong growth. This, together with its glossy green foliage, its white star-shaped flowers and its bright red fruits, renders it an attractive hedge plant. It is armed with quite heavy thorns. The fruits are edible and have been appreciated by many of those who have tried them at the station. The species is being further propagated.

The Eden pineapple has fruited for the first time at the station. The other hybrid pineapples are now making a good growth but none have produced fruit.

Coleococcus amicarum. Through the kindness of Mr. W. S. Lyon, of Manila, a successful introduction was made of this economic plant. The five plants have been planted out.

Rattan palm, *Calamus* sp. (Dæmonorops). Through Mr. H. P. Wood, Secretary of the Hawaii Promotion Committee, two introductions of seeds of rattan palm have been made from Java. A large percentage of these have germinated and are doing well.

REPORT OF THE CHEMIST

By W. P. Kelley

The work of the chemical department during the past year has been devoted to the following lines of investigation: A study of the pineapple soils of Oahu; an investigation of the fertilization and nutrition of rice; fertilizer experiments with cotton; and miscellaneous.

PINEAPPLE SOILS.

The pineapple soils throughout the islands are, for the most part, located above the cane lands at elevation of from 600 to 1,000 feet. At least two-thirds of the land devoted to this crop is situated on the upland plain between the Koolau and Waianae mountain ranges of Oahu. This section is subjected to extremely variable climatic conditions, especially as regards rainfall. Some months a very heavy precipitation, to the extent of 10 or more inches, followed by a very dry period, produces in the soil wide variations. From the very beginning of this industry it has been the practice to grow pineapples continuously on the same land with little or no rotation of crops; although some of the growers fallow their land one or two years out of every five. In many instances the farmers, on account of the presence of various insects, have been induced to burn or remove from the land every vestige of the old plant before preparing for a new crop; and while it is true that the fruit alone does not make very heavy drafts on the soil, any single crop system, coupled with the burning or removing of plant residues, is an exhaustive one, and one that is likely to produce ill consequences.

Even if the ash of the old plants be left on the soil, thus returning to the land the minerals taken from it in the growth of the previous crop this practice robs the soil of the nitrogen which the previous crop consumed. Not only is the soil in this way robbed of its nitrogen, but any humus, which the organic matter is capable of producing, is also destroyed. The active forces that predominate in these soils at the high temperatures,

which prevail throughout a large part of the year, bring about a rapid oxidation of the organic matter in the soil; and any system that involves removing from this land the organic matter produced thereon without the growing of green-manuring crops or the application of humus-producing manures, leads to bad physical, chemical, and biological conditions in the soil.

Furthermore, these soils contain large amounts of finely divided ferric hydrate, which becomes gelatinous when wet, and has a high water-holding power.[1] During the periods of heavy rainfall the soil becomes saturated with water, and in consequence of its fine state of division, large percentage of ferric hydrate, etc., the water is held tenaciously. Organic matter, on the other hand, would tend to make the land more porous and thus bring about better drainage.

The growers have observed from the outset that the soils in this section naturally fall into two classifications as regards color,—black and red soils. Influenced by the fact that black soils are almost universally regarded as rich soils, the prospective growers, at the begining of this industry, eagerly sought the soils of dark color. But it has been found subsequently that the red soils are naturally better adapted to pineapples than these black lands. Usually the plants present a peculiar appearance on the black soils, and do not grow as successfully as on the red land. The fruit on the black soil is characterized by a whitish-pink color, lack of flavor and an excess of acidity. The red soils, while producing large yields of excellent fruit at the beginning, yield diminished harvests with each subsequent planting. These practical difficulties have brought about a demand on the station for assistance in the way of analyses of soil samples and for advice in regard to the use and selection of fertilizers.

Recognizing the importance of this crop, and the need of scientific information as regards these soils and their fertiliz ation and management, the station has undertaken an extensive investigation of the questions involved. After some preliminary investigations and a general study of the conditions and practices in the three principal areas of this island, a series of forty fertilizer plat experiments was begun on the red and black soils, respectively, and in each instance, on land that had previously produced two or more crops of pines. The principal objects in

[1] Soils, by Hilgard, p. 196.

making these experiments were to determine the fertilizer requirements of pineapples on each of these types of soil; and to ascertain whether or not it is possible, by the use of fertilizers, to maintain the original yields of fruit. On the black soil it was hoped to find some practical means of overcoming the yellow color of the plants. The red soil experiment is located on the land of the Hawaiian Pineapple Company at Wahiawa, and after thorough tillage and good preparation, fertilizers were applied and pineapple plants transplanted on September 8, 1908. The black soil experiment is located on lands of the Wahiawa Consolidated Pineapple Company, the fertilizer being applied and the crop transplanted on September 19.

About eighteen months is required from the time of planting until the first harvest, and therefore, it is too soon to draw final conclusions in regard to the relative officiency of various fertilizers used in the experiments. But without attempting to discuss these in detail, it may be said that certain combinations of fertilizing substances are producing thrift and vigor, whereas others are not proving so effective.

At this time, however, the author wishes to further emphasize the importance of the very best possible drainage for pineapples, especially on the red soils. The fertilizer experiments on the red soil are located on a gentle incline, but unfortunately, the rows on part of this experiment run at right angles to the direction of natural water flow; and although open ditches are maintained every thirteenth row, that is about fifty feet apart, the drainage on this part of the experiment has not been effective. Furthermore, the same combinations of fertilizing substances that are producing good effects on the better drained portion of the experiment, are not producing similiar effects on the more poorly drained portion. Various applications of different fertilizers to this red soil by the growers have often given promise of good harvests, but it frequently develops at some period in the growth of the crop that there is something else lacking in the soil besides available plant food. Often the plants grow satisfactorily some months after planting, especially if this happens to be during a period of comparatively light precipitation, but later it is observed that there are scattering plants, or sometimes spots of considerable size on which the plants are not growing well. These appear to be stunted, often

reddish-yellow in color around the outer edges of the leaves; and upon pulling up such plants, it is found that the roots are dead and the whole underground part of the plant is water-soaked, sometimes fermenting and half rotten. Such conditions seem to be most frequent and make their first appearance following a period of continued rains or a deluge. In several authentic cases, a heavy downpour caused an overflow of ditches, and consequently a flooding of the land, and in the course of a few days the plants on the flooded areas showed just the appearance pointed out above. Even here the water could not stand above the surface because of its rolling topography, but there was brought about such a saturated condition of the soil that, on account of its high water-holding capacity, due to its high percentage of ferric hydrate, and low humus content, aeration was largely shut off; and stagnation ensued, a condition which the pineapple plant will not tolerate.

During the continued dry weather of last fall, the author found that wherever water had flowed over the soil or the soil had been previously saturated, the plants were not thrifty, and in many instances had died. In such places it was almost impossible to force a spade into the soil, so compact and dry had it become. The incorporation of organic matter in this soil will undoubtedly increase its aeration by enlarging the air spaces and would prevent a serious compacting of the soil and bring about a more uniform distribution of soil moisture; thus effectually preventing stagnation during the time of rains and enabling the soil to hold an optimum of water for a much longer period after rains and at the same time greatly lessening the tendency of the soil to become dry and hard during periods of rapid evaporation. An excess of stagnant water also brings about a bad biological condition, and in soils like these, which contain a relatively large percentage of ferrous oxid, a saturated condition contributes to the formation of considerable amounts of ferrous carbonate and ferrous sulphate, bodies which are known to be plant poisons. In addition, nitrification is seriously interfered with, and possibly the solubility of certain minerals is changed.

In connection with the field experiments, a laboratory study of these soils has also been undertaken. A large number of samples of each type of soil has been analyzed, and some extremely interesting and abnormal conditions have been found.

The following table fairly represents the chemical composition of each of these types of soil:

Table showing water-free composision of some pineapple soils.

	RED					
	SOIL	SUBSOIL	SOIL	SUBSOIL	SOIL	SUBSOIL
	Laboratory No. 5	Laboratory No. 6	Laboratory No. 7	Laboratory No. 8	Laboratory No. 13	Laboratory No. 14
Insoluble matter	43.79	38.64	40.89	39.25	46.52	46.37
Potash (K_2O)	.62	.73	.51	.60	.50	.57
Soda (Na_2O)	.20	.30	.21	.32	.31	.13
Lime (CaO)	.46	.46	.51	.66	.32	.31
Magnesia (MgO)	.41	.35	.37	.38	.40	.42
Iron (Fe_2O_3)	26.11	32.54	35.72	33 28	24.37	24 49
Alumina (Al_2O_3)	10.82	10.45	3.58	8 66	9.15	12.02
Manganese (Mn_3O_4)	.27	.19	.22	.06	.33	.35
Phosphoric acid (P_2O_5)	.13	.16	.07	.08	.09	.13
Sulphur (SO_3)	.08	.04	.09	.07	.11	.12
Volatile matter	13.73	14.06	14.22	13.99	15.98	13.17
Total	100.15	100.60	100.22	100.09	100.28	100.13
Nitrogen (N)	.24	.22	.34	.25	.38	.25
Acidity[a]	1960.00		1568.00		392.00	

	BLACK					
	SOIL	SUBSOIL	SOIL	SUBSOIL	SOIL	SUBSOIL
	Laboratory No. 9	Laboratory No. 10	Laboratory No. 11	Laboratory No. 12	Laboratory No. 15	Laboratory No. 16
Insoluble matter	33.45	36.06	39.02	42.60	33.73	34.53
Potash (K_2O)	.83	.74	.78	.81	.99	1.07
Soda (Na_2O)	.40	.42	.36	.44	.21	.38
Lime (CaO)	1.39	.86	.64	.60	.49	.37
Magnesia (MgO)	.54	.43	.41	.39	.52	.41
Iron (Fe_2O_3)	19.65	21.51	18.24	20.52	26.03	26.85
Alumina (Al_2O_3)	15.50	15.74	15.40	16.89	15.82	18.98
Manganese (Mn_3O_4)	9.74	8.76	4 80	3.50	4.01	2.43
Phosphoric acid (P_2O_5)	.21	.16	.36	.13	.35	.21
Sulphur (SO_3)	.16	.09	.23	.05	.17	.05
Volatile matter	17.73	14.45	19.71	13.72	16.68	12.83
Total	100.33	100.31	100.35	100.23	99.85	99.79
Nitrogen (N)	.39	.23	.45	.19	.35	.20
Acidity[a]	neutral		196.00		98.00	

[a]Calculated to pounds CaO per acre foot.

The above table shows that the two types of soil differ materially in but one point, namely, as regards their respect-

ive manganese content. Since determining that the black soil contains such large percentages of manganese, a thorough investigation of the entire pineapple section has resulted in establishing that all the black soils in this section contain relatively large percentages of manganese; and that there is a close correlation between the manganese content of these soils and the general appearance of the pines. It is not deemed necessary at this time to go into a detailed discussion of this work since a preliminary report has already been issued [1] and the investigation is still under way. It may be said, however, that the manganese in this soil is in an extremely soluble form, even more soluble in weak solvents than any, or all, of the other constituents of the soil combined. It appears that the form of manganese is influenced by the growth of pines, in that it is changed into a higher state of oxidation; and furthermore, such change is detrimental to the growth of the plant. Plants grown on manganese soil are found to contain a higher percentage of manganese than those grown on the red soil, and to possess a markedly different oxidizing power as measured by the rate at which water extracts of the plant change the color of alcoholic solution of guaiacum, etc. This investigation is being continued with a view of determining what influence manganese has upon other constituents of the soil, their solubility, etc., its effects on nitrification and the physics of the soil. A detailed study of the absorption of nutrients of the pineapple plant at the various stages of its growth, on both types of soil, is also being undertaken. Soils of similiar somposition are very rare, and it has been deemed wise to make a study of manganese in its relations to plant growth in general, since here we have an opportunity of studying the effects of this element under natural conditions.

RICE INVESTIGATIONS.

For some years this station has been investigating the rice industry in these islands, reports of which work may be found in the Annual Reports for 1907 and 1908; and in these, the importance of this crop and some of its economic phases have been emphasized. Several fertilizer tests have been made and

[1] Hawaii Sta. Press. Bul. No. 23.

the relative practical economy of various fertilizers has been pointed out. In consideration of the importance of this crop, the conditions under which it is grown, and the old established oriental practices of fertilization, which prevail in rice culture here, and that chemical fertilizers are generally applied when the crop is two-thirds grown, it has been deemed wise to devote some time to a study of some of the more fundamental questions regarding the absorption of nutrients by the rice plant, etc. When it is considered that rice is grown in submerged culture, and therefore variations in composition due to variations in available water supply, are eliminated, it is at once apparent that this crop readily lends itself to fertilization investigations.

Accordingly, in January, 1909, in conjunction with the agronomist, this department instituted a series of fertilizer plat experiments on the rice trial grounds of the station. The object of these experiments is not only to determine the efficiency of various fertilizers, as measured by increased yields of paddy and straw, but to determine at what period in the growth of the rice plant the various nutrients are absorbed, and some of their inter-relations and functions. In these investigations samples from the several plats have been taken at different periods in the growth of the plant. These were separated into their botanical parts and a chemical analysis of each is being made. The cultural part of the work is being done by the agronomist. This work is now in progress and will probably not be completed for some months, since it is hoped to duplicate the experiment with a spring and fall crop. Results of scientific interest, have, however, already been obtained, as for instance, the rice from the plats, which receive certain fertilizers, has been found to have a materially different composition, as regards the nitrogen content, from those without fertilizer. The large amount of analytical work, involved in such an investigation, necessarily prolongs the time of completion; but it is hoped that the data may be ready for publication during the present fiscal year.

FERTILIZER EXPERIMENT WITH COTTON, AND MISCELLANEOUS.

The growing interest in cotton, as a new industry in Hawaii, is sufficient justification for an investigation of every agricultural phase of this crop, and with the knowledge of the import-

ance of fertilization of sugar-cane the prospective cotton growers naturally desire information in regard to the fertilization of this crop. Consequently, in February, 1909, a series of fertilizer plats was laid out on each of the two extensive cotton experiments referred to in this report by the agronomist. It is entirely too soon to draw conclusions from these experiments further than to point out that on each of the experiments it is already apparent that the application of phosphates has greatly increased the growth of the plants.

A small amount of miscellaneous analytical work has been done, such as the analysis of an occasional sample of water, fertilizer, soil, etc.; but it is the policy of this department to confine its efforts, as largely as possible, to a few lines of research, and only in so far as it is necessary in the cooperation of other departments, will miscellaneous work be accepted.

REPORT OF THE AGRONOMIST

By F. G. Krauss.

Rice and cotton investigations continue to be the main lines of work of this division. The rice expriments were begun in 1906, and the cotton work in the early spring of 1908. As a part of these investigations, considerable attention has been given to the testing of field crops with a view to developing cultures suitable for rotation with rice and cotton, and if possible, adapting some of the crops to green manuring. It is recognized that the permanent conservation and upbuilding of our soils is as important as to increase immediate production, and a rational system of crop rotation, together with practical schemes for green manuring are important practices looking to that end. Constant effort is being made to encourage cooperative field experiments with planters, and the past year has seen greater strides in this direction than ever before.

RICE EXPERIMENTS.

The work with rice consists of testing new varieties and the development of pure strains of the best types; experiments to determine the best methods of culture; and fertilizer experiments, together with the testing of crops suitable for rotation or substitution.

The problems affecting the artificial fertilization of the rice crop continue to receive much attention and the results of the work have already aided growers materially in increasing their yields. However, it is recognized that to be of greatest permanent value, work of a more fundamental nature is necessary. Accordingly, in January, the chemist and agronomist planned a series of experiments looking to that end. The cultural end of the investigation has been undertaken by the writer and the chemical work by the chemist.

CO-OPERATIVE FERTILIZER EXPERIMENTS.

Based on the results obtained in a previous experiment,[1] the Palama Rice Plantation on Oahu, consisting of approximately 100 acres, which had not previously used chemical fertilizers, undertook in the spring of this year, under the station's direction, the use of some eighteen tons of a high-grade complete fertilizer of the following composition:

6 per cent nitrogen (3 per cent organic, as fish guano, 3 per cent as sulphate of ammonia).

9 per cent phosphoric acid (4 per cent as water-soluble, 5 per cent as reverted).

10 per cent potash as sulphate of potash. The net cost of the fertilizer was $870.00, or $8.70 per acre. To this should be added transportation and cost of application, which would bring up the cost to approximately $10.00 per acre.

A careful survey of the entire plantation, in company with the proprietor, during April and May indicated that the general fertilization was very effective on all the lands except those near the sea. On May 1st, when the crop was well headed out, the total yield of paddy was estimated at 180 tons as against 131 tons for the previous spring crop.

On May 20, a few days before the beginning of the harvest, a visit was made to the plantation preparatory to making the test weighings. The first field inspected showed the work of a destructive army worm (*Leucania unipuncta*), the full extent of the damage becoming more and more apparent as the inspection progressed. The aid of the station entomologist was called in, and it was soon found that the scourge was prevailing over a wide extent of the rice territory, both on Oahu and Kauai. The damage had been done quickly and was over almost before any one was aware of the pest. This attack of an insect pest on rice was absolutely without precedent in the Hawaii industry. A full report upon the pest will be found in the report of the entomologist.

The total ultimate yield of the crop was 104½ tons of paddy, the smallest crop ever recorded for this plantation, and this, under conditions otherwise the most promising in its history. Some idea of the destructiveness of the caterpillar may

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[1] Cooperative Experiments, Hawaii Sta. Rpt., 1908.

be obtained from the fact that one field, consisting of twelve acres, yielded only 11,015 pounds of paddy against 35,000 pounds, harvested the previous season. This was one of the best fields and the first patch to be attacked.

Within the above area a fertilizer experiment, covering 2½ acres, was under way at the time of destruction, so that no more reliable data could be obtained from it than from the general fertilization.

Below are given the yields of the spring and fall crops of the Palama Rice Plantation during the past five years, which may serve to give some insight into the production end of the industry under favorable general conditions and careful management.

YIELDS OF PADDY (STANDARD HAWAIIAN RICE), FROM A 100 ACRE PLANTATION FAVORABLY LOCATED AND CAREFULLY MANAGED.

Year	*Spring Crop.* *Pounds.*	*Fall Crop.* *Pounds.*
1905	335,708	417,680
1906	262,335	353,469
1907	346,434	359,093
1908	256,300	370,168
1909 [1]	209,366	....

TESTING AND DEVELOPING NEW VARIETIES OF RICE.

Since the beginning of the rice investigations in 1906, the testing and developing of old and new rice varieties has formed an important part of the work of this division. Up to the present time 166 varieties have been tested in comparison with each other, and as to their adaptability for spring or fall culture. The more promising varieties have been grown for from two to six generations. During the past year, as heretofore, the agronomist personally selected a large number of individual rice panicles from among the growing crops of the leading plantations for breeding purposes. The principal growers were also invited to make selections according to their own ideal

[1] Low yield due to unprecedented destruction by army worm.

type. These were further gone over in the laboratory and the best selections propagated with a view to establishing pure strains.

Rice No. 19 (S. P. I. No. 12508) introduced in the fall of 1907, is now believed to be firmly established. Its bad mixture with other types, due to careless harvesting, has been remedied by the propagation of 10,000 seedlings individually during the past fall. The seedlings were set 10 by 10 inches apart and carefully rogued. The yield from a fifth of an acre was 704 pounds pure seed. The entire amount has been distributed among growers in lots of 50 to 100 pounds, sufficient to plant 2½ to 5 acres, if the seed is carefully conserved. It is hoped that fully 50 acres will be planted for the fall crop of 1909.

The difficulty in milling this rice economically, appears to have been overcome by one of the Chinese millers who reports that by thoroughly drying the paddy, setting the millstones far apart, and running them rather more slowly than is the usual practice, he has avoided the high percentage of breakage hitherto experienced. A very satisfactory sample was turned out during the past season and one grower marketed 100 bags at a satisfactory price.

As in the past considerable upland rice seed has been distributed in the hope that this grain would find favor as a cured fodder for horses. No extensive planting has as yet been reported. In a cooperative experiment at the Kunia lands, on Oahu, where the rainfall is very light, a small planting of the two most promising varieties, Nos. 65 and 68, has given promise of being well suited for culture on large areas now devoted to pasture. If the present high price of imported hay continues, there can be but little doubt that the growing of this crop will prove profitable.

COTTON EXPERIMENTS.

These experiments were begun in the spring of 1908 and were briefly reported upon in the annual report for that year. In March of the present year the experimental data to date were reported in Press Bulletin No. 24, entitled "Preliminary Report on Cotton Experiments."

In January of the presence year a collection of thirty varieties and selections of cotton, representing four more or less

distinct types, were planted for comparative test of yield, quality of lint and habits of growth. Considerable attention is being given to the selection of superior individual specimens, with a view to obtaining desirable mother plants from which to breed pure strains. The importance of the new methods devised for the propagation of cottons, i. e., by cuttings or budding, whereby all the qualities of a given individual plant may be perpetuated indefinitely, becomes more and more apparent as the work progresses. A brief review of methods and results will be found below. Pruning experiments, as applied to plants entering their second season of growth, are likewise under way and will be reported upon more fully at the end of the present harvest.

It may be said at this time, that the Sea Island types respond best to low pruing, i. e., when a mere stump, three to six inches in length, is left . Pruning to tall canes, 15 to 30 inches long, resulted in considerable "die back," the basal shoots almost invariably exceeding the growth from terminal buds. A further advantage in low pruning, which should not be lost sight of, is the fact that the entire removal of the old wood, with its adhering trash, destroys possible insect infestation, which might cause trouble with the new crop. In fact, this phase of growing cotton as a perennial is the most objectionable that has as yet been advanced. In the case of the Caravonica types of cotton, cutting back from one to three fourths of the previous season's growth, appears to give the best results. Being of exceedingly rank growth, too severe pruning causes excessive wood growth at the expense of fruit, and furthermore, such rank growth is extremely brittle. This causes bad splintering in heavy winds. When it is remembered that the Caravonica cottons give their lowest yields during the first year after planting, while the Sea Island apparently give their greatest, or at least optimum yields the first season, some good reasons for the practices outlined become apparent. In the case of the upland cottons, low pruning insured a larger percentage of plants being carried over into the next season than high pruning, but when the plant survived pruning to spurs, similar to the methods adopted by the California grape growers, such plants greatly outyielded the low pruned. However, since only a small number of specimens were available for the pruning experiment, it is

possible that the heavy fruiting plants were naturally more vigorous to begin with. Plate IV illustrates the different systems of pruning described above.

Attention has already been called to the more vigorous growth of the Caravonica cottons over other varieties thus far grown. To this characteristic is laid its late fruiting, and as frequently happens, its shyness to bear fruit,—the two objections that have been advanced against this variety. In digging up a number of plants, it was found that they possessed exceptionally prominent tap-roots, and also strong lateral root systems compared with other varieties. In one striking case, and several lesser ones, it was found that transplanting both hastened and made more profuse the subsequent fruiting.

Growing Cotton from Cuttings.

Plate V illustrates the total cuttings made from a single first season plant, which, in this instance, produced 36 soft-wood, or tip cuttings; and 31 hard-wood, or butt cuttings. The former averaged about eight inches in length, and the latter, twelve inches. It is frequently possible to obtain a hundred or more cuttings from a single Caravonica plant.

The general character of the cuttings is shown in the lower illustration of the plate.

Plate VI illustrates the relative growth of good average Caravonica cuttings. The growth, while not equal to that obtained from seed propagation, is quite satisfactory and likely to be improved as the method is perfected. The plant shown in figure 2, began producing "squares" when less than five months old, which is considerably earlier than seedlings bear; but this cannot be said to be desirable if the ultimate yield is affected, which seems probable.

Budding Cotton.

So far as the writer is able to ascertain, the credit for the first practical demonstration of budding, as applied to the cotton plant, is due Mr. E. C. Smith of Pearl City who, with Mr. E. W. Jordan, are pioneers in the culture of Caravonica cotton. In the fall of 1908, Mr. Smith successfully budded one Caravonica into the stock of another cotton of the same variety.

Six buds were inserted in a ten-months-old tree in November and the illustrations in Plate VII show the plant during the following July. The small figures, 1-6, in figures 2 and 3, show the points of budding. Figure 1 shows the tree before pruning, and figure 3, after the tree was pruned. Up to the time of pruning, when the harvest was practically over, this plant bore 90 mature bolls, producing 15 ounces of seed cotton. Figure 4 illustrates the prunings from which the cuttings illustrated in Plate V were made.

The method used was that commonly termed "shield-budding." The method is simple, rapid and effective, so that its application in field culture is eminently practicable.

Grafting has not yet been attempted and seems to offer no particular advantages, except, perhaps, in the case of old trees, such as are now growing on the station grounds. In this case the cleft-graft would seem the best suited.

General Cultural Notes.

While the cotton experiments are now only in their second year, several important general principles appear to be fairly established as essential factors in the culture of cotton in Hawaii, as based on personal observations and experiment.

Soils and Locations.—Deep, well drained, silty loam soils, on the leeward side of Oahu, and from sea level up to 750 feet elevation, appear to be well suited to the culture of cottons generally, without the aid of irrigation, in seasons of normal rainfall, from 20 to 30 inches per annum.

The dry, broken coral lands, skirting Oahu from Honolulu to Sisal, would also appear well suited to cotton, the E. C. Smith experimental patch of Caravonica cottons being a fine example of possibilities in this region.

The sandy low lands and lower slopes of a large area in the Koolau district of Oahu would seem well suited to Sea Island cotton, judging from samples received from that locality.

A twenty-five acre field of Caravonica cotton located at Makaweli, Kauai, gives great promise in the possibilities of cotton growing in that region without the aid of irrigation.

With the exception of sisal, and possibly pineapples, cotton would appear to be as drougth resistant as any crop now grown

in Hawaii; and it is believed that the crop can be grown successfully over a wide area without irrigation.

Tillage.—The importance of deep and thorough tillage has been well demonstrated during the present summer, as well as last year. A fine example of what deep plowing and constant surface cultivation will accomplish, is demonstrated on the Kunia lands, where with only 24 inches of rainfall during the 12 months preceding June 30, a perfect growth has been maintained up to the present time, and the crop promises a large yield. The same is true of the Makaweli experiment. Twenty-five acres are involved in each of these experiments. At the trial grounds, in a dry, gravelly soil, ample moisture has been maintianed to bring a large crop to maturity by thorough surface tillage, preceded by a deep plowing, preparatory to planting. At the station grounds, where cultivation was curtailed on account of interference of the unpruned plants entering their second year's growth, the plants have suffered for the want of moisture.

Varieties.

No question is more often asked than the suitability of different varieties. The question is a hard one to answer at this time. From a cultural standpoint, it may be said in general, that the Caravonica type is the most drought resistant when once established. In well prepared land it sends its prominent tap-root down deeply into the soil. On the thin coral soils, and the compacted substrata at the station grounds, this variety shows physiological qualities that appear to make it less subject to drought than the Sea Island types. As a perennial plant, in localities with long rainless summers, there can be no doubt as to its adaptability. Sea Island cotton will make a good crop with a very moderate amount of moisture, but requires intensive tillage. Dry weather hastens maturity, but excessive moisture produces rankness of growth. It is believed that the low lands, bordering the sea, are best adapted to this variety. The best samples and largest proportionate yield were obtained in Hauula, and it is believed that the windward district of Oahu is generally adapted to Sea Island, while the leeward district is better adapted to the Caravonica and upland types.

Sufficient experimental data are not yet at hand to speak

authoritatively concerning the Egyptian cottons. This type is now being grown at Kunia, the Waipahu uplands and at the station trial grounds. In all these places the plants have thriven remarkably well. It has the general habit of the Sea Island type, but is a much ranker grower, the wood being very brittle in consequence, as is also characteristic of the Caravonicas. It matures intermediate between Sea Island and Caravonica, and thus far promises to out-yield all other types as an annual. Owing to its natural rank growth, it is believed that this variety is unsuited to wet localities in this warm climate.

The following varieties of cotton are now under test: *Sea Island type*—Seabrook, one strain of Georgia Sea Island; one strain of Florida Sea Island; five station selections of Sea Island. *Egyptian*—four strains of Mit Afifi, one strain of Ashmouni. *Upland*—Roger Big Boll, Triumph, Sunflower, Southern Hope, Parker, Chinese, Peterkin, Duke Long Staple; *Caravonica*—"Wool" [1], Caravonica "Silk," Caravonica Kidney.[2]

The above will be reported upon in detail at end of the harvest.

Two wild native Gossypiums (*G. tomentosum*), a low spreading shrub, 4 to 6 feet high, bearing yellow flowers and a short dark brown lint; and *G. drynarioides,* an arborescent type, bearing large, red Hibiscus-like flowers, and yielding a very dense dark brown lint, similar to the preceding), are being propagated with a view to using them as a basis for breeding work; it is believed some striking results may be obtained from crossing these varieties with commercial forms of cotton. The drought resistant qualities, and dark colored lints of these types is what especially commends them for the work in hand.

Time of Planting and Distances to Plant.

Season and location determine the time to plant. For warm, well drained soils, any time after January 1 and up to the first of March, is recommended regardless of variety, unless the season for harvest, whether for weather or labor conditions, must be considered. In cold, wet localities, planting had best be delayed till March or April.

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1 In their second year of growth.
2 In their fourth year of growth.

Past experience would indicate that the smaller types of cotton, such as Sea Island and upland, should be planted 2 by 4 feet apart in dry locations, and 2½ by 5 feet apart in moist locations. For the Caravonica cottons, twice the above distances are recommended, and for Egyptian, an intermediate spacing. If to be grown as a perennial crop, every alternate plant in the row should be removed the second or third year. It is strongly urged that only one plant be left in a hill.

Improving a Strain.

As Hawaii must always depend upon the quality of her cotton product, rather than bulk, it becomes important that only the highest quality of fiber be maintained. To do this successfully, the planter must early acquaint himself with the qualities that constitute a superior type and work constantly for that ideal.

Should cotton be grown successfully as a perennial in Hawaii, it should be practicable in time, after having found the exceptional individual plant, to work over by budding an entire plantation to this type.

Two extensive cooperative experiments with cotton on a field scale, were begun in the early part of the year and will be reported upon in a later publication.

MISCELLANEOUS EXPERIMENTS.

The Chinese and Japanese matting sedges, (*Cyperus tegetformis* and *Juncus effusus*), which have been under test during the past two years, are holding their own, and a large stock of plants are available for distribution. Of the three plantings made by parties under the station's suggestion, the larger planting, covering about one and one-half acres, has not proved a success owing to the drying out of the pond to an extent never before known. Subsequently, the pond became flooded and the reeds took a new lease on life.

The two other plantings, each one-half acre in extent, are thriving and represent extreme conditions; the one, on submerged upland marsh, overflowed by fresh spring water; the other, a tide-water marsh too salt for any other culture.

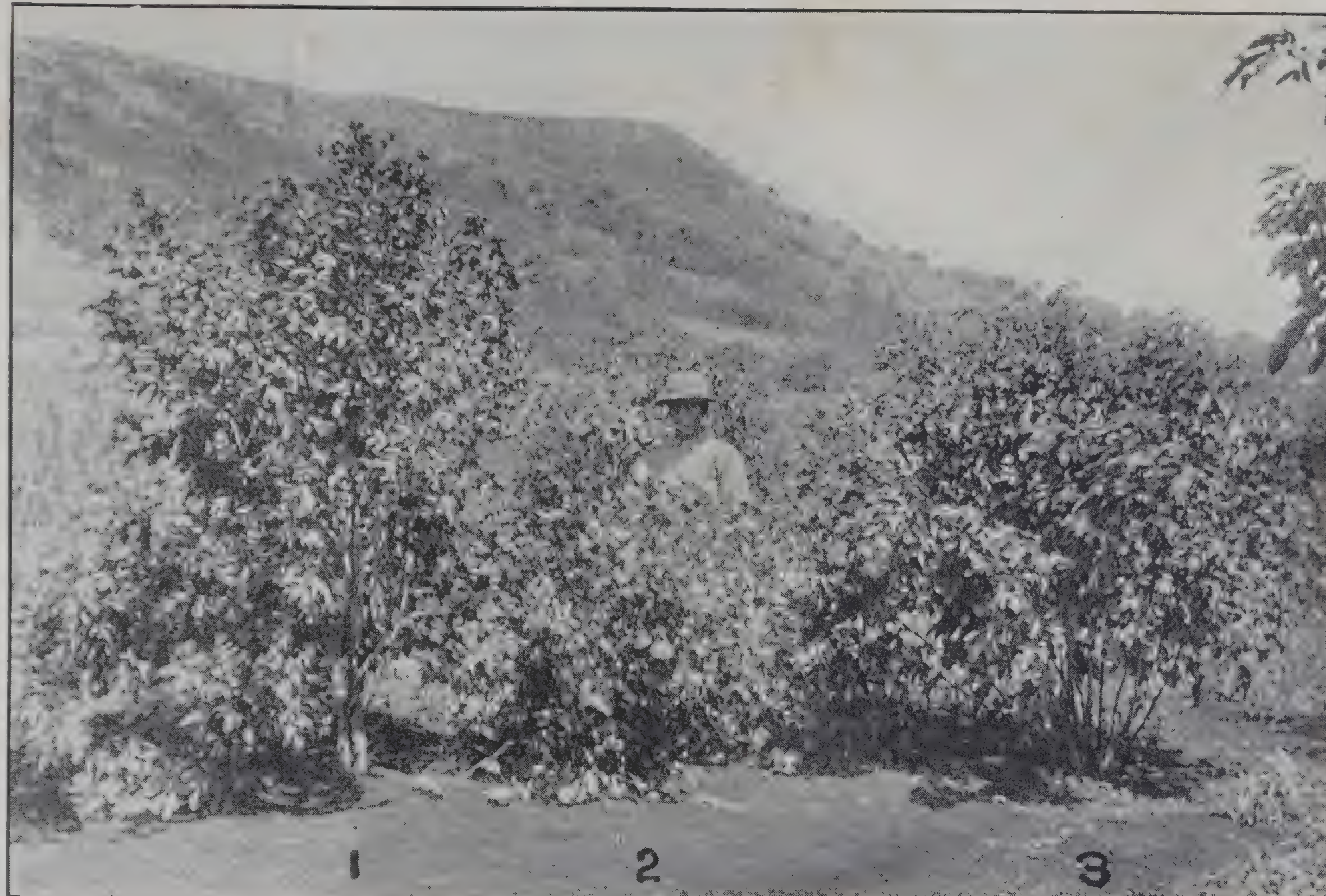
During the year a comparative test was made of some fifty fodder and green-manuring plants, including alfalfa, cowpeas,

peanuts, soy beans, velvet beans and numerous other legumes; also corn, dry-land rices, wheat, oats and some perennial grasses. Numerous selections were made of the choicest individual plants, and a large amount of seed distributed.

This department in common with other departments of the station, prepared both a federal and territorial exhibit for the Alaska-Yukon-Pacific Exposition. The specimens collected were all agronomic and consisted of 128 items for the federal and about an equal number but larger samples for the territorial exhibit.

Acknowledgement is due the station staff for much valuable assistance rendered this division.

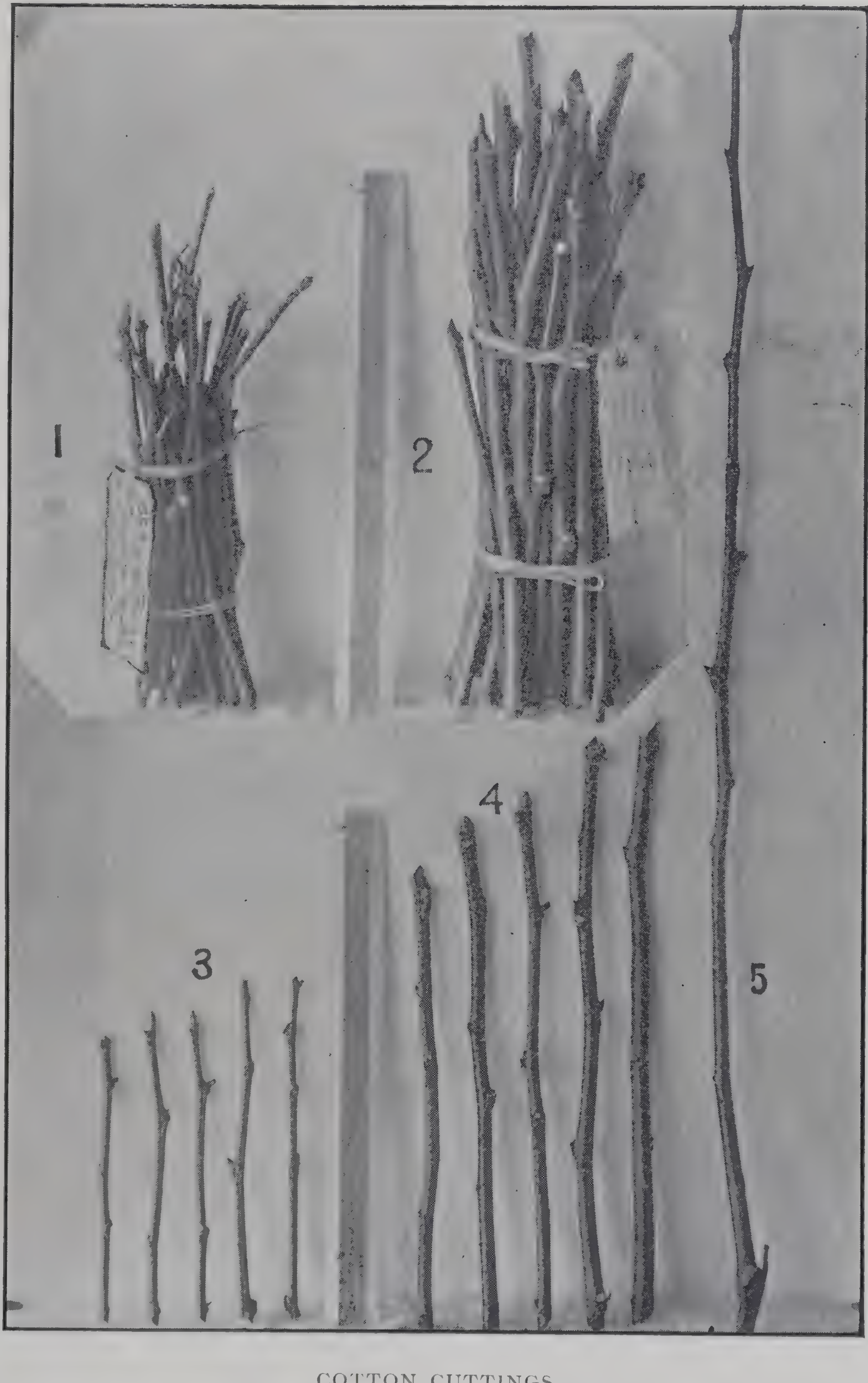
PLATE IV.



THREE YEAR OLD PRUNED CARAVONICA COTTONS

1. Tall Pruned. 2. Low pruned, 3. Intermediate

PLATE V.



COTTON CUTTINGS

1, 3, Tip or soft wood cuttings. 2, 4, Butt or hard wood cuttings.

5, Dormant wood, suitable for making cuttings, or cion for budding or grafting.

PLATE VI

FIG. 1.

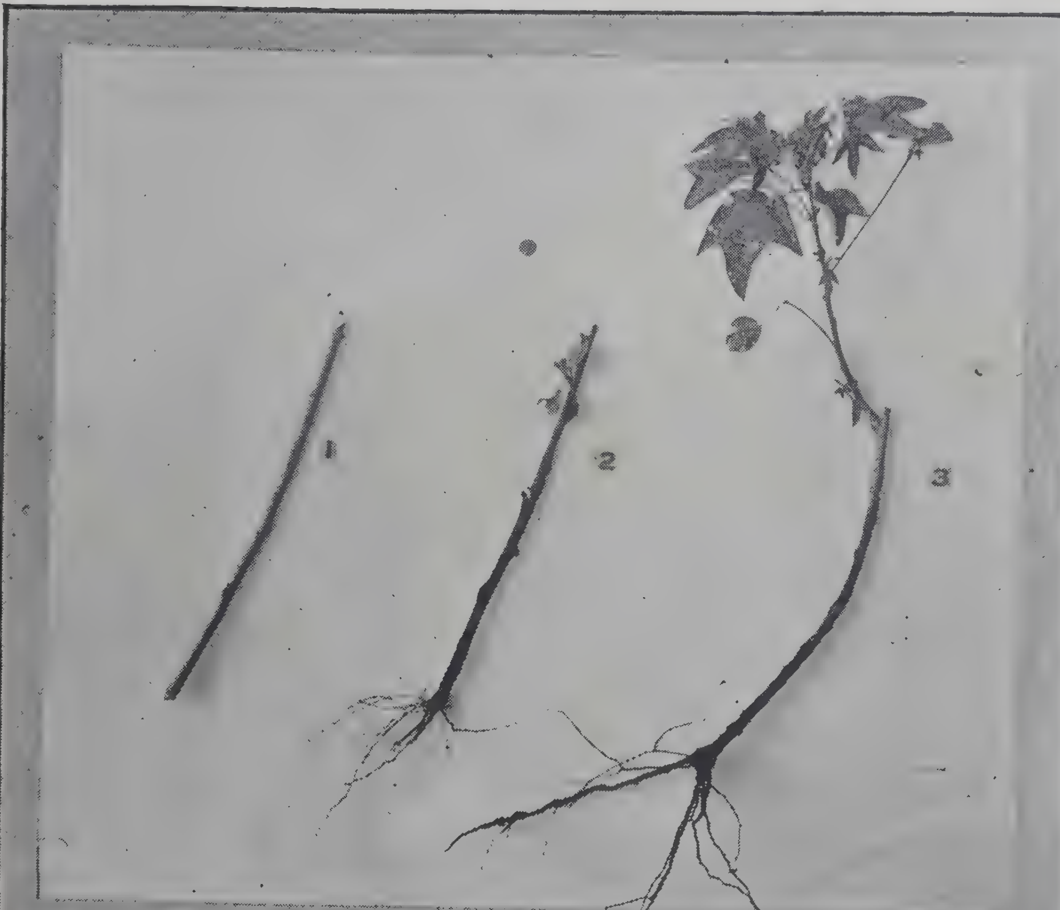
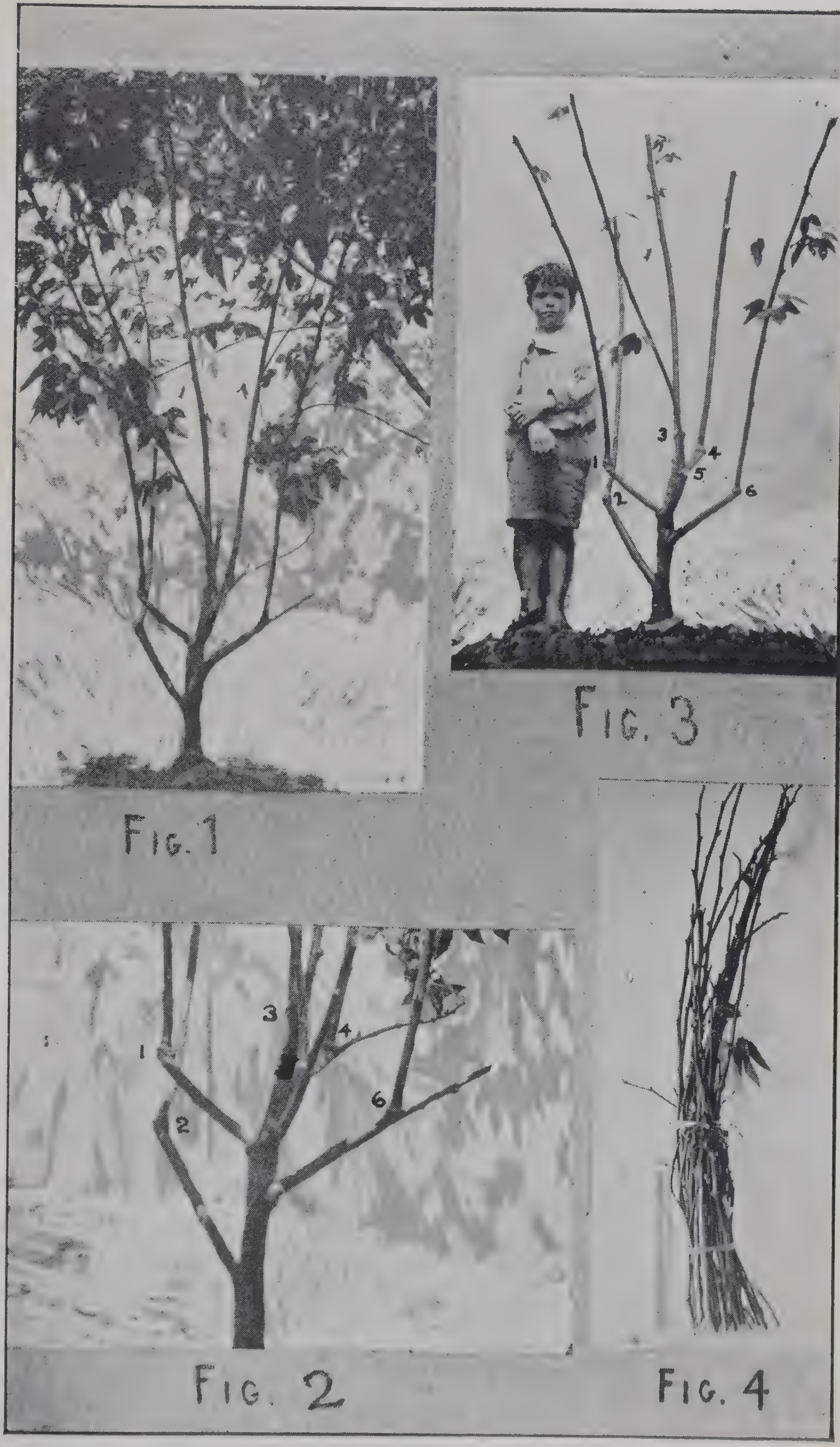


FIG. 2.

CARAVONICA COTTON GROWN FROM CUTTINGS.

PLATE VII.



BUDDED COTTONS

Rego
6. 8. 12
44

1324 Issued May 6, 1911.

HAWAII AGRICULTURAL EXPERIMENT STATION,

E. V. WILCOX, Special Agent in Charge.

ANNUAL REPORT

OF THE

HAWAII AGRICULTURAL EXPERIMENT STATION

FOR

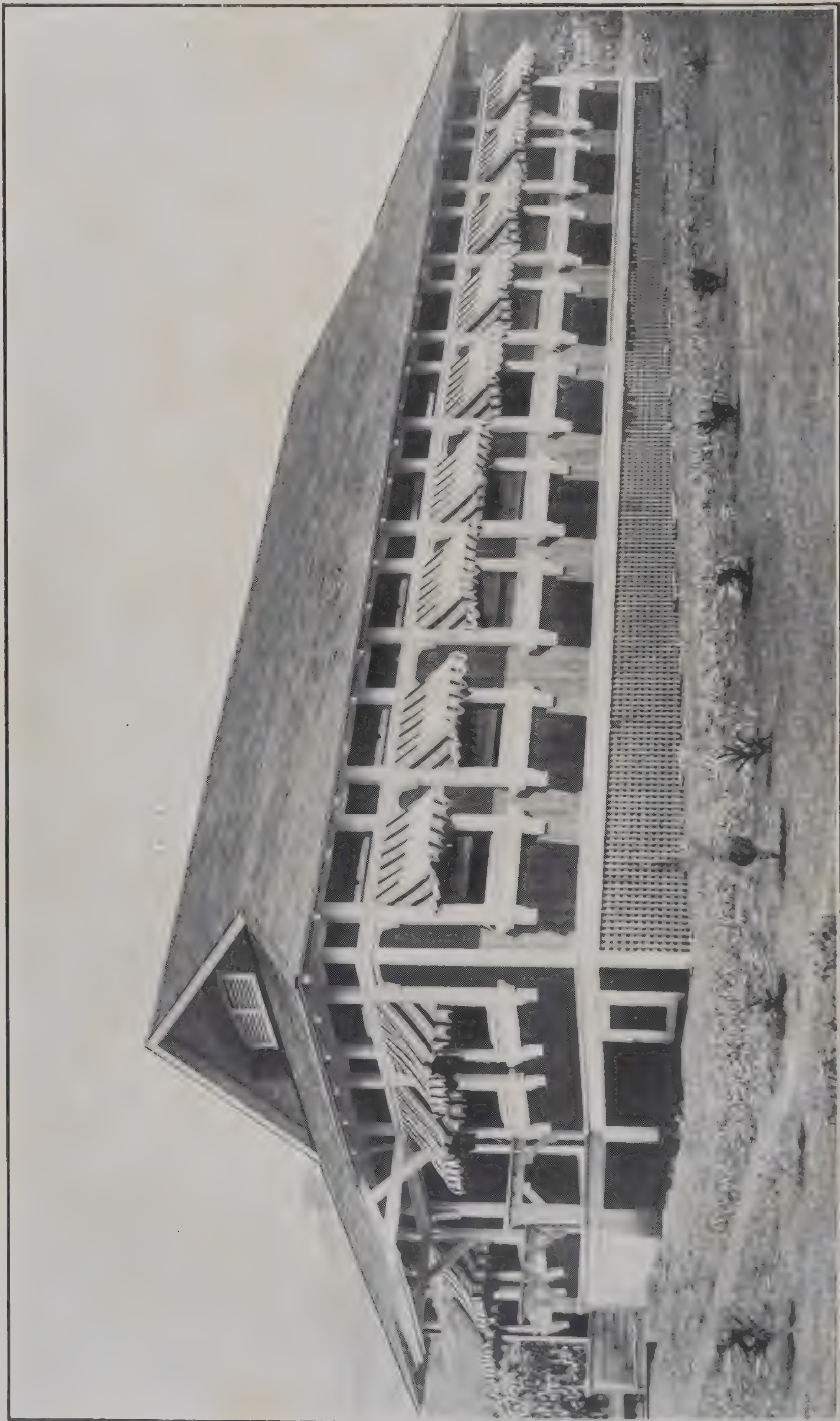
1910.

UNDER THE SUPERVISION OF

OFFICE OF EXPERIMENT STATIONS,

U. S. DEPARTMENT OF AGRICULTURE.

WASHINGTON:
GOVERNMENT PRINTING OFFICE.
1911.



NEW OFFICE AND LIBRARY BUILDING.

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HAWAII AGRICULTURAL EXPERIMENT STATION, HONOLULU.

[Under the supervision of A. C. True, Director of the Office of Experiment Stations, United States Department of Agriculture.]

Walter H. Evans, *Chief of Division of Insular Stations, Office of Experiment Stations.*

STATION STAFF.

E. V. Wilcox, *Special Agent in Charge.*
J. Edgar Higgins, *Horticulturist.*
F. G. Krauss, *Agronomist.*
W. P. Kelley, *Chemist.*
D. T. Fullaway, *Entomologist.*
Alice R. Thompson, *Assistant Chemist.*
C. J. Hunn, *Assistant Horticulturist.*
V. S. Holt, *Assistant in Horticulture.*

LETTER OF TRANSMITTAL.

HAWAII AGRICULTURAL EXPERIMENT STATION,
Honolulu, Hawaii, October 25, 1910.

SIR: I have the honor to transmit herewith and to recommend for publication the Annual Report of the Hawaii Agricultural Experiment Station for the fiscal year 1910.

Respectfully,

E. V. WILCOX,
Special Agent in Charge.

DR. A. C. TRUE,
Director Office of Experiment Stations,
U. S. Department of Agriculture, Washington, D. C.

Publication recommended.

A. C. TRUE, *Director.*

Publication authorized.

JAMES WILSON, *Secretary of Agriculture.*

CONTENTS.

ILLUSTRATIONS.

PLATES.

TEXT FIGURES.

ANNUAL REPORT OF THE HAWAII AGRICULTURAL EXPERIMENT STATION FOR 1910.

SUMMARY OF INVESTIGATIONS.

By E. V. Wilcox, *Special Agent in Charge.*

BUILDINGS.

During the fiscal year ended June 30, 1910, a new office building (frontispiece) was erected from funds generously supplied by the Territory of Hawaii. The new building is better lighted than the old one; gives room for a more convenient library, and also offices for the special agent in charge, clerical force, entomologist, and agronomist, as well as for a mailing room. The chemical laboratory in the old cement building was inconvenient and has, therefore, been rearranged and new tables have been constructed for analytical and general work. A more efficient hood has also been devised for carrying off the fumes, and a new room arranged for nitrogen determinations.

GROUNDS.

Some of the land nearest Honolulu belonging to the experiment station has been heretofore in an uncultivated and unimproved condition. During the year this land was cleared and planted in Bermuda grass for lawn purposes or in various crops used in experiments. In addition, about 10 acres of land, lying on the slope of the station grounds, at an elevation of about 250 feet, has been thoroughly cleared of shrubby undergrowth and about one-half of it has been planted to cotton and other crops. The chief buildings belonging to the station are erected on grounds which heretofore belonged to the Navy Department and which were temporarily turned over to the use of the Agricultural Department. During the fiscal year this land was definitely transferred to the Department of Agriculture by an agreement reached between the Secretary of the Navy and the Secretary of Agriculture.

DEMONSTRATION FARMS.

It has been felt for some time that on account of the fact that the Territory consists of several islands, located at considerable distances apart, demonstration farms were desirable in order to bring the work of the station more prominently before the inhabitants of the other islands of the group as well as on Oahu. The problem of establish-

ing demonstration farms in Hawaii is somewhat different from that which must be met in the States of the mainland. Farming communities are composed of different races, and a large proportion of the farmers who have small holdings are quite unacquainted with the purposes of demonstration farms. It appears, therefore, inadvisable to carry on such work according to the methods long in vogue on the mainland.

The objections to those methods, in so far as Hawaii is concerned, are chiefly two. Perhaps the more important is the matter of funds, which are at present inadequate to carry on demonstration farms on each of the islands independently of private help. The Territory has freely offered to turn over the necessary land to the station for such experiments, but the Territorial funds available for station use are not adequate for the maintenance of independent demonstration farms. There would be required a large outlay for fencing, buildings, machinery, horses or mules, foremen, and laborers. Such an arrangement would also result in the production of a considerable amount of material which would have to be sold in the open market. An objection has been made to this on the grounds that the station would, in a sense, be competing with practical farmers and with an unfair financial advantage.

The second objection to the mainland program of demonstration farms follows from the nature of the farming population in Hawaii. A community of Portuguese and native farmers can best be persuaded to adopt improved methods, actually shown to be advantageous, when these methods are put in operation upon farms belonging to one of the most progressive farmers in each community. It therefore seems best to establish demonstration farms essentially on the basis of a cooperative experiment. Several such farms will be put in operation during the fall of 1910. The program consists essentially in making an arrangement with one of the best farmers in each community to adopt certain modifications of cultural methods which the station will suggest and to keep careful record of the results of such work for the use of the station and all his fellow farmers. By this method it is believed that the results shown on the demonstration farms will be more readily accepted and will more obviously meet the exact conditions under which the farmer must labor.

COOPERATIVE EXPERIMENTS.

During the time which has been occupied in determining upon a practical method of carrying on demonstration farms, practically the plan outlined above has been put in operation on a number of large estates. The station has undertaken the supervision of certain cultural, soil, and fertilizer experiments on Molokai, Maui, Hawaii, and Oahu. The crops involved in these experiments are pineapples,

cotton, rubber, corn, legumes, rice, sorghum, and a number of miscellaneous forage crops. These cooperative experiments have in all cases moved along very smoothly, for the reason that the private individuals concerned were intensely interested in bettering their cultural methods and establishing more extensive areas of cultivated crops, and also, for the reason that a highly intelligent and reliable control was exercised over the management of the experiments and the keeping of records. While cooperative experiments on the mainland and elsewhere, in many instances, cause considerable annoyance to both the station and the private individuals concerned, the cooperative experiments in Hawaii have been strikingly free from such troubles. So long, therefore, as the work can be carried on with relatively little interference with the time and energy of the station staff, it seems highly desirable to continue them where satisfactory arrangements can be made. It is a pleasant duty to acknowledge the active and intelligent interest which has everywhere been shown in the cooperative experiments thus far carried on by the station.

RATIONAL SOIL PROGRAM.

The soils of the Hawaiian Islands are very different in several respects from those which are familiar to farmers and agricultural workers on the mainland. In the first place, the Hawaiian soils contain high percentages of iron in various forms (say from 15 to 30 per cent). In addition to the high iron content, the soils contain more titanium than mainland soils, and in some localities, also a large amount (up to 9 per cent) of manganese. The presence of the large quantity of iron in Hawaiian soils gives them physical properties which are seldom met with in soils on the mainland. Wherever special attention is not given to cultivation, the soils rapidly become impervious to water and air and the iron present in the soil is reduced to the ferrous state. This, as is well known, is injurious to plant growth and is instrumental in preventing adequate aeration of the soil. Moreover, when the iron exists in the ferrous state and the soil can not be aerated, the use of fertilizers gives little or no benefit. It is therefore necessary to adopt a rational soil program, with the central idea that of securing a better aeration and better physical properties of the soil. Studies, which are designed to throw light on the practical methods of accomplishing such a result, are now in progress at the station, and the suggestions, already made by the station chemist, are being put into practice in a number of localities. It may be truthfully said that in many localities the chief soil problems are concerned with the physical rather than the chemical properties of the soil. Improper aeration not only causes the iron to become reduced to the ferrous state, but may also prevent the utilization by the plant of the plant food naturally present in the soils.

The study of cultural and rotation methods for securing a better aeration of the soil will be continued during the coming year, both in pot and field cultures.

RICE.

The chemical work on rice during the fiscal year was concerned chiefly with the study of the time or stage of growth at which fertilizers should be applied and the influence of various elements of plant food upon the composition of the rice plant. It was found during these experiments that the program adopted by the growers, in using fertilizers on rice, was somewhat ill advised, as judged by the physiology of the rice plant. It appears that the rice plant, by the time it is two-thirds grown, has already taken up about four-fifths of the nitrogen and phosphoric acid, and nine-tenths of the potash which will be absorbed during its whole growth; and that, therefore, fertilizers should preferably be applied before planting the rice, or, at any rate, during the very early stages. The value of nitrogen in rice culture has proved in the station experiments to be greater than was previously suspected. On some of the rice soils the use of phosphoric acid and potash gives no beneficial results. On these soils nitrogen alone produces as heavy yields as do complete fertilizers.

It was soon noted in experimenting with fertilizers on rice that nitrate of soda appeared to produce no beneficial effect, while ammonium sulphate was very active in promoting growth and yield of grain. This point has been carefully studied through two crops of rice at the trial grounds, and through several series of pot experiments. In almost every instance nitrate of soda gives no increase of growth over that observed in check plats or check pots; in fact, while it may be too early to conclude positively, the pot experiments thus far carried out indicate that the rice plant can not use nitrogen in the form of nitrate, but only in the form of ammonia. It had already been suspected by other investigators that ammonia was better than nitrate for rice, but it has hitherto never been shown that the rice can not use nitrogen in the form of nitrate.

The importation of rice from Japan continues to increase, and the production of rice in Hawaii has slightly decreased. In order to get further information on the cause of this condition, and to learn more in detail the methods of rice cultivation in Japan and the varieties used in that country, the agronomist visited Japan and China during the past year. It was found that the Japanese have a decided preference for certain varieties of rice which are almost the only kinds exported to Hawaii for use by the Japanese population, and that these varieties are claimed to have certain superior culinary qualities which can not be definitely described. Seed of about 150 varieties of rice was brought back from Japan, including a considerable quantity of seed of four of the best varieties grown in that

country. These have been distributed to growers and reports regarding their behavior are expected during the coming year. A test of fertilizers on a commercial scale will be carried out for the purpose of demonstrating the results which have already been obtained at the trial grounds and in pot cultures. It is believed that these demonstrations will lead to a change of method in the application of fertilizers, resulting in greater economy and increased growth.

Experiments are also under way with a number of legumes and other crops, some of which were recently imported from Japan, to be used in rotation with rice in order to maintain the high yield which has hitherto prevailed in Hawaii.

COTTON.

Experiments with cotton were begun by the station three years ago and have yielded striking results in certain localities in which commercial plantings, to the extent of about 500 acres, have been made. During the coming year these plantings will be greatly increased. A number of points have been quite clearly demonstrated during these experiments. It has been shown that cotton will thrive under a wide range of rainfall—from 25 to 100 inches per year—and at a considerable variation of altitude, from sea level to 1,600 feet. The most favorable locations, however, are low-lying lands near the seashore and protected by algaroba, or other windbreaks, from the winds which occur during the winter. Although at elevations below 300 feet a temperature as low as 50° F. is very rare in Hawaii, nevertheless, at such a temperature cotton shows the effect in a marked degree. The leaves even may turn brown, as if they had been frosted. With regard to rainfall, a moderate amount per year is decidedly more favorable for the growth of cotton than a higher or lower rate of precipitation.

One difficulty which has been experienced in growing Sea Island cotton in Hawaii is that of excessive yield, which results in a too prostrate form of growth. In one locality on the windward side of Oahu, where the rainfall is about 70 inches per year, 2 acres of Sea Island cotton required about 5,000 props in order to keep the branches from lying upon the ground and causing the bolls to rot. In this respect the Caravonica cotton is superior to Sea Island, since it invariably has an upright habit of growth. The difficulty experienced with the prostrate habit of the Sea Island can be appreciated from a consideration of the fact that in the 2-acre field just mentioned and in another 1-acre field, on the leeward side of Oahu, the average number of bolls per plant was 700, and on one tree 1,200 bolls were counted at one time. This produces a weight under which the slender branches of the Sea Island can not support themselves in an upright position. An elaborate series of pruning experiments is now under

way with the idea of learning a method by which an upright growth can be induced in the Sea Island cotton, at least for the second and subsequent years of the crop. Some promise is already held out by these experiments. A strain of Sea Island, secured from one of the best plantations on James Island, S. C., shows a more upright habit of growth than any other strain of Sea Island which has thus far been secured.

The Caravonica cotton continues to give promising results. During the first year of its growth the yield appears to be normally low, but in the second year a heavy yield is obtained, which, in conjunction with the greater ease of picking and the higher percentage of lint, makes a choice between Sea Island and Caravonica somewhat doubtful. Egyptian cotton has given results as satisfactory as those obtained with Sea Island. The strains of Egyptian cotton with which the station is experimenting grow rather more vigorously than the Sea Island, and the yield is perhaps slightly larger. The place which Egyptian cotton should take in the agriculture of Hawaii will largely be determined by the future demands of the market for the three chief types of cotton now grown in the Territory. In addition to Sea Island, Caravonica, and Egyptian cottons, experiments are being made with Chinese upland, a number of varieties of upland from the Southern States, and a cotton with red lint, from Cuba. It is proposed to make a reciprocal cross between Sea Island and Kidney cottons in order to determine whether Caravonica cotton was originated in this manner and whether an improvement upon the ordinary type of Caravonica can thus be secured. Several plants have been found in different localities in the Territory where a natural cross between a pure Sea Island and a pure Kidney cotton could have taken place, and these plants strikingly resemble, in habit of growth and quality of lint, the ordinary type of Caravonica cotton.

It has been found that pure strains can be propagated by means of cotton cuttings, and a number of cuttings will come into bearing during the present season. In addition to this method of propagation budding has been tried on a large scale. Propagation is an easy matter by the method of budding, but the economy of the method on a commercial scale has not yet been determined. According to the present outlook it seems an economic proposition to bud over large areas with bud wood from the best plants, and thus secure a uniform cotton over the whole field. This method would, of course, have no value except where cotton is cultivated as a perennial crop.

PINEAPPLES.

In connection with the study of manganese in the soil as affecting the growth of pineapples, experiments have been made with a number of crops which could possibly be grown in rotation with pineapples or

to replace pineapples in the manganiferous soils. For this purpose corn, rice, and various other cereals, tobacco, cotton, legumes, garden vegetables, and fruit trees were used. It has been found that manganese invariably causes a yellowing of all the leaves and a premature falling of the lower leaves on all plants with which experiments have been made. The plants may subsequently become green, just before the fruiting period, at which time a vigorous growth may be observed for a short period. The ultimate outcome, however, is in all instances a decidedly stunted growth and small yield. The root system in manganiferous soils is peculiar in the length and fineness of the small roots. The ultimate outcome in pot experiments is a root system strikingly different from that in ordinary garden soils. Apparently the extreme fineness of the roots is due to the lack of resistance which they meet in penetrating manganiferous soils. These soils invariably remain loose like ashes, no matter how frequently or heavily they may be irrigated.

In the fertilizer experiments with pineapples, which are being continued by the chemist, it has been found that phosphates, particularly acid and reverted phosphates, have a beneficial effect upon the growth of the pineapple plants, probably for the reason that these materials tend to render the manganiferous salts in the soil less soluble. Lime, on the other hand, is decidedly injurious on manganiferous soils, as shown by the experiments of the station and by tests which have been tried by growers on a commercial scale. The injurious effect of lime is possibly due to the fact that it helps to furnish conditions favorable for the formation of the higher oxids of manganese, which are the most injurious salts of this mineral.

A study of the ripening of pineapples has disclosed the fact that the sugar content of the fruit is derived exclusively from the leaves of the plant and does not increase after the fruit has been removed from the plant. If pineapples are picked green and allowed to ripen the sugar content at complete ripeness is the same as it was when the fruit was removed from the plants. An analysis of the fruit shows that they contain no substance which can be changed into sugar during the ripening process. Fruits picked too green and allowed to ripen, therefore, lack greatly in sugar content and in flavor. The sugar content of green fruits, or fruits ripened after being picked too green, is about 2 or 3 per cent, while that of fruits ripened on the plant ranges from 9 to 15 per cent. The ripening process in fruits picked green appears to consist largely in a softening of the tissues. A microscopic examination of sections of green pineapples shows that the cell walls in the parenchyma of the fruit are greatly thickened, but become extremely thin in ripening. It is obvious from these facts that in order to obtain a good flavor in fresh fruit the fruit should not be picked until the sugar content has

become fairly high and the fruits have turned yellow to the extent of about one-fourth their length at the base.

HORTICULTURAL INVESTIGATIONS.

Satisfactory progress has been made in propagating avocados, especially by budding. The method reported in the last annual report has been put into operation on other trees, and the results thus far obtained are very promising. A number of difficulties, particularly the drying of the bud, have been successfully overcome.

Attention has been given to the varieties of avocados to be found in the Territory. There appear to be quite a number of recognizable varieties, but most of them have not been definitely named. Four varieties of special merit have received attention on account of their being especially adapted to shipping, extra late, extra early, or of exceptional quality.

Similarly with mangoes, the methods of propagation reported in the last report and in Bulletin 20 of this station, have continued to give good results. In one case fruit was borne upon a graft within eighteen months after insertion. Continued tests of the possibility of transplanting mango trees have shown that this operation is relatively simple and successful in the majority of cases. The insect pests and fungus diseases of avocados and mangoes have not proved to be especially serious when proper treatments are applied.

A large collection of papaya seed was made from trees in various localities whose fruit was reported to be of special value or of excellent flavor. From the observations made on papayas there seem to be two distinct types (diœcious and monœcious), in Hawaii, with various intermediate forms. The diœcious type occasionally has a fruit borne among the staminate flowers. The monœcious type of papaya bears fruit on every tree. The monœcious type has both perfect and staminate flowers on the same tree and is the one which lends itself best to breeding and selection. As long as the diœcious type is used one must depend upon cross-fertilization, and the characters can not be fixed as readily as where close fertilization can be carried on. Moreover, when the diœcious type is used, a certain percentage of trees will prove to be males, and therefore sterile. A large amount of space in the orchards is thus lost, as well as the time which has been expended in cultivating the male trees. There is considerable evidence that ultimately a strain of papayas will be produced which will come true to seed. Since seed is the only apparent practical means of propagating papayas, it seems wise to make every possible effort to obtain seed with fixed characters.

It was considered desirable to learn the state of the market in San Francisco for sweet potatoes during the season when sweet potatoes are not to be had in that city from local sources. For this purpose

two shipments were made from the station, with the result that all varieties, of whatever color, if of standard size, were accepted at 8 cents per pound in San Francisco. The market price of sweet potatoes in Honolulu is usually from 70 cents to $1 per hundred. It would be, therefore, obviously a good practice to make at least one planting of sweet potatoes for the purpose of shipment to California sometime during the interval between the first of May and the middle of July.

ENTOMOLOGICAL INVESTIGATIONS.

During the year the attention of the entomologist was directed to a number of miscellaneous insect outbreaks, to the insects of the sweet potato, and certain enemies of forage crops, and to the propagation of parasites, particularly for the algaroba bean weevil. A bulletin on sweet potato insects has been prepared and will be issued during the coming year. Considerable time has been spent in studying the insect enemies of corn, and it is proposed to take up a study of the chief pests of the principal forage crops in Hawaii as occasion may offer.

More than 2,000 parasites of bean weevils, obtained through the Bureau of Entomology of the United States Department of Agriculture, in mesquite pods, were reared at the station and turned out at various points on Oahu, Maui, and Molokai. The result of this importation of parasites is not yet apparent, but one egg parasite appears to have become quite effective during the past season.

RUBBER.

Opportunity was had during the year to visit all of the commercial rubber plantings of the Territory. These are located on the windward side of Maui and in the Puna district of Hawaii. A satisfactory growth is manifested everywhere in the rubber plantations between the lowest altitudes and an elevation of 1,400 feet. No commercial plantings have been made at higher elevations. On all of the plantations Ceara rubber grows much more rapidly than Hevea rubber. The latter does not make as rapid growth in Hawaii as it is reported to make in the Straits Settlements and Ceylon. The question whether Hevea should be extensively planted in Hawaii seems to depend on whether the ultimate yield will be enough larger than that of Ceara to counterbalance the long waiting period for the first tapping.

Wherever clean cultivation has been adopted, the growth of the trees is incomparably more rapid than where no cultivation has been practiced. Trees which have received clean cultivation since planting are larger at 2 years of age than 6-year-old trees which have not been cultivated. The necessity of cultivation is apparently, for the

most part, due to the lack of aeration and the presence of stagnant water in the soil. As soon as cultivation is begun the soils allow the passage of water much more freely and drainage is decidedly better.

Where the rocky nature of the soil will not permit cultivation, it is necessary to destroy the weeds by other means, and a comparative experiment has been made to determine the effectiveness of sulphate of iron and arsenite of soda as herbicides. The cost of spraying with arsenite of soda is a little less than with sulphate of iron, and its effectiveness appears to be greater. About 500 acres of land in the rubber plantations have been sprayed with arsenite of soda. This land is of a rough nature and is covered with both shrubby and herbaceous weeds of a great variety. From one to three applications of arsenite of soda are required to clean the land of all vegetation. Even lantana and other shrubby plants are killed down to the ground by the spray. The total cost for material and labor ranges from $1.25 to $2 per acre; the expense, is, therefore, much less than that incurred by hand or horse implements. Arsenite of soda has also been used at the station on a number of weeds, including Japanese nut grass, which is probably the worst weed in cultivated land in the Territory of Hawaii. This weed is killed down to the ground by a single application of either arsenite of soda or sulphate of iron. It sprouts up again after a considerable interval, but the young plants are weak and may be destroyed by a second application.

TARO.

There are lands in the Territory which are known to have been cultivated almost continuously to taro for several hundred years. The station has made an arrangement to carry on a fertilizer test on a taro plantation which has been continuously in this crop for 200 years. In some fields of the plantation a decided diminution in yield has been noticed. On account of the active interest which the plantation managers take in the matter, this is believed to be a particularly favorable opportunity to learn the fertilizer requirements of taro and to compare them with conditions met in rice culture under water.

BROOM CORN.

A considerable quantity of broom-corn seed was distributed to growers in different parts of the Territory, and about 1 acre was planted on the station grounds. The seed was planted rather late, and the crop was, therefore, attacked by plant lice to a most unusual extent. The growth of uninfested plants was quite satisfactory, and heads of normal size are now forming. If the cultivation of broom corn proves to be a paying line of farming, it is proposed to build a broom factory in Honolulu for the local trade.

REPORT OF THE ENTOMOLOGIST.

By D. T. Fullaway.

GENERAL NOTES.

During the year the usual insects were noticed attacking agricultural crops. Some recently introduced pests have increased to an alarming extent and exemplify the destructiveness of harmful insects in the absence of natural enemies. Outbreaks of cutworms and army worms occurred in many localities during the winter, causing severe losses. The rice crop was not affected this year, but several wheat fields were devastated. The corn leaf aphis contributed to the destruction of the wheat and barley crops. In the fall pineapple plants on the Consolidated Pineapple Co.'s plantation were badly damaged by an introduced locustid, *Xiphidium varipenne.* The insect attacked the leaves of the pineapple, making large abrasions which permitted the entrance of fungus hyphæ, causing the leaves to wilt and die back. This feeding habit is very extraordinary for the insect, which usually feeds on pollen. The eggs of the locustid are much parasitized, so that it is not likely to become a serious pest of pineapples. The injury, in fact, has not continued. The edible nuts of the litchi tree in several Honolulu gardens were badly attacked in July by a tortricid moth, *Cryptophlebia illepida.* The larvæ bore into the succulent fruit and render it unfit for use. On the trees of one private orchard practically the entire crop was destroyed. An attempt was made the present year to prevent this loss by spraying, but the crop of nuts was small, and the moth did not appear to be very troublesome, although it was present as usual in klu and koa pods.

Some attention was given to bee keeping, but nothing done in the way of investigation. It is a pleasure to record that this minor industry is now well established here. The bee keepers are progressive, and the industry is growing. One corporation keeping bees has gone extensively into queen rearing, and during the last year several Japanese and Australian apiaries were supplied with queens from these islands. No new bee plants were introduced, but the better of those already secured were rather freely distributed.

Numerous inquiries which were received during the year in regard to insect pests and remedies for them were answered by correspondence. In some cases personal inspection of the conditions was made

and advice offered. The station's collection of economic insects was maintained and much material added. New office rooms and much new and better equipment were secured.

While matters of immediate concern received due attention, the work of the entomologist was, as far as possible, confined to definite lines of investigation. This kind of work is believed to be more progressive and permanent than scattered efforts with an immediate object in view.

ALGAROBA WEEVIL PARASITES.

At the beginning of the year shipments of bean weevil parasites were received through the cooperation of the Bureau of Entomology, United States Department of Agriculture, and much time was given to taking care of the material, securing the parasites, and releasing them. Later a search was made to find if they had become established, but this could not be verified except in the case of the minute egg parasite (Trichogramminæ), which bred freely from the eggs of bean weevils on beans brought in from the field. The following is a detailed report of this attempted introduction:

Lot 1 (June). One box of pods of the mesquite, infested with *Bruchus prosopis* and *B. amicus*, from Dr. F. H. Chittenden. Parasites obtained from this lot were all *Heterospilus* sp.

Lot 2 (July). Three boxes of mesquite beans containing *B. prosopis* and *B. amicus*, from Mr. W. D. Hunter. Parasites obtained were *Heterospilus* sp. and *Urosigalphus bruchiphagus*.

Lot 3 (August). One large box containing 30 pounds of mesquite beans with *B. prosopis* and *B. amicus*, from Mr. W. D. Hunter. Parasites obtained were *Heterospilus* sp., *Urosigalphus bruchiphagus*, *Eurytoma tylodermatis*, and Trichogrammid.

Lot 4 (August). Two boxes containing *B. prosopis* and *B. amicus*, from Mr. W. D. Hunter. Parasites obtained principally *Heterospilus* sp.

Lot 5 (September). Two boxes containing *B. prosopis* and *B. amicus*, from Mr. W. D. Hunter. Parasites obtained were *Heterospilus* sp. and *Urosigalphus bruchiphagus*.

Lot 6 (September). One large box containing 30 pounds of mesquite beans with *B. prosopis* and *B. amicus*. Parasites obtained were *Heterospilus* sp., *Urosigalphus bruchiphagus*, *Eurytoma tylodermatis*, *Cerambycobius cushmani*, and Trichogrammid.

All attempts to breed the parasites in confinement failed. The parasite house, which offered the only secure place for breeding work, was too dry and hot. In the breeding house it was necessary to place the material in breeding jars and there the beans molded. Under the circumstances it was necessary to liberate the parasites at once and allow them to take their chances in the field. On advice, only

Heterospilus sp. was released, and in all 2,303 were liberated—a fair proportion being males, with which the females had been confined from five to ten days before liberation. This parasite has not been seen since. The parasites were mostly liberated on the grounds of the experiment station. One lot of 250 specimens was released on the Alexander and Baldwin plantation at Puunene, Maui; another lot of 200 on the Isenberg ranch at Waialae, Oahu; and another lot of 100 on the Molokai ranch near Kaunakakai. Attempts to breed *Eurytoma tylodermatis*, of which probably 50 were obtained, in confinement were unsuccessful.

INSECTS OF FIELD CROPS.

Considerable time was given during the winter to the investigation of the insects affecting field crops. The greatest hindrance to the diversification of agriculture in these islands has been the ravages of insects, and numerous attempts to grow cereals and the ordinary field crops have ended in failure, owing to sudden and severe attacks of insect pests which have been half-heartedly and unsuccessfully coped with. The object of the investigation was to learn what insects attack field crops and their method of attack, in order to suggest means of combating them successfuly. An excellent opportunity was offered to begin this kind of a study in the 200-acre experiment at Kunia, on this island. The locality in which the Kunia Development Co.'s operations are being conducted is typical of much of the land that is available for diversified farming. It was new land, without water, and close to the mountains. All the elements of chance in diversified farming were present. The results of the first year's cultivation suggested plainly that success or nonsuccess depends largely on whether or not effective measures are adopted to suppress insect pests and are applied with thoroughness.

The crops under observation were corn, wheat, barley, oats, jack beans, and cotton.

CORN.

The following insects were observed to attack corn:

Cutworms (*Agrotis ypsilon* and *A. crinigera*).[1]
Army worm (*Cirphis unipuncta*).[1]
Grass army worm (*Spodoptera mauritia*).[1]
Looper (*Plusia chalcites*).
Angoumois grain moth (*Sitotroga cerealella*).[2]
Corn leaf aphis (*Aphis maidis*).[3]
Corn leafhopper (*Peregrinus maidis*).
Rice weevil (*Calandra oryza*).

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[1] Hawaiian Sugar Planters' Sta., Div. Ent. Bul. 7, 1909.
[2] Hawaiian Planters' Record, 2 (1910), No. 2, p. 102.
[3] Hawaii Sta. Rpt. 1909.

Wireworm (*Simodactylus cinnamomeus*).
Tenebrionid beetle (*Epitragus diremptus*).
Cryptoblabes aliena.[1]
Batrachedra rileyi.[1]
Amorbia emigratella.[2]
Opatrum serratum.
Adoretus tenuimaculatus.
Aræcerus fasciculatus.
Plodia interpunctella.
Ephestia elutella.
Setamorpha sp. (Reared by Swezey.)
Catorama mexicana. (Reared by Swezey.)
Nitidulid. (Reared by Swezey.)

WHEAT.

The following insects were observed attacking wheat:
Cutworm (*Agrotis crinigera*).[3]
Army worm (*Cirphis unipuncta*).[3]
Grass army worm (*Spodoptera mauritia*).[3]
Looper (*Plusia chalcites*).
Leaf roller (*Omiodes localis*).[4]
Corn leaf aphis (*Aphis maidis*).[5]
Opatrum serratum.
Epitragus diremptus.
Wireworm (*Simodactylus cinnamomeus*).

BARLEY.

The following insect was observed on barley:
Corn leaf aphis (*Aphis maidis*).[5]

JACK BEAN.

The following insects were observed on the jack bean:
Grass army worm (*Spodoptera mauritia*).[3]
Leaf miner (*Agromyza* sp.).

COTTON.[6]

The following insects were observed attacking cotton:
Cutworm (*Agrotis crinigera*).[3]
Grass army worm (*Spodoptera mauritia*).[3]
Cotton aphis (*Aphis gossypii*).[5]

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[1] Hawaiian Sugar Planters' Sta., Div. Ent. Bul. 6, 1909.
[2] Hawaii Sta. Bul. 22, 1910.
[3] Hawaiian Sugar Planters' Sta., Div. Ent. Bul. 7, 1909.
[4] Hawaiian Sugar Planters' Sta., Div. Ent. Bul. 5, 1907.
[5] Hawaii Sta. Rpt. 1909.
[6] Hawaii Sta. Bul. 18, 1909.

Many of these pests are discussed in technical papers, in which life histories, remedies, natural enemies, etc., are given. References to these papers are made opposite the name of the insect. The following notes of observations at Kunia in connection with these crops are offered:

Cutworms and army worms undoubtedly did the most damage to the corn. Plants several weeks old in sections of the fields were so badly eaten that replanting became necessary. In other sections plants were literally stripped, both stalk and ear. The lower leaves were badly frayed and skeletonized by *Plusia chalcites* and the young larvæ of *Spodoptera mauritia*, but this injury is negligible. The corn leafhopper and corn leaf aphis are at times very injurious, especially to young plants. The ripening ears were attacked by *Cryptoblabes aliena*, *Amorbia emigratella*, and *Batrachedra rileyi*, which work in the silk at the flower end, also eating some of the cob. These insects attacking the standing corn are to be expected and can and ought to be systematically fought. For cutworms and army worms, the use of light traps in addition to poison bait is suggested. It might also be profitable to spray or dust the plants once or twice with arsenate of lead. The aphis and leafhopper may be sprayed with tobacco decoction, but they are difficult to control artificially.

The insects which attack matured ears or stored corn, such as the Angoumois grain moth, corn seed weevil, etc., can be best controlled by fumigating the stored corn. Corn stored in a tight bin may be fumigated with carbon bisulphid, 1 pound to 1,000 cubic feet; if the storeroom is not tight, the dose should be doubled.

Cutworms, army worms, and corn leaf aphis did the greatest damage to the wheat and barley, and in order to grow these grains it seems essential to control these pests in some way. The remedies suggested above are the only practical ones that can now be recommended, but the present situation might be greatly altered by the introduction of good parasites for this class of pests.

The dipterous leaf miner infesting jack beans gave this crop a very ragged appearance, and in sections the plants were eaten down to the ground by the army worm. The leaf miner is parasitized and is troublesome only at times. The army worm can be controlled with the remedies mentioned above.

The cotton aphis and climbing cutworms did the most damage to the cotton during the winter. The aphis was particularly bad, becoming so abundant as to cover both stems and foliage, and killing some plants. It is difficult to control by artificial means, but a spray of kerosene emulsion or tobacco decoction might be beneficial. Climbing cutworms should be fought with poisoned bait or by spraying with arsenate of lead.

In the spring the insects attacking the sweet potato were studied. The sweet potato is extensively cultivated here and is a staple article of food, especially among the Hawaiians and poorer classes. It has a number of insect enemies which damage the crop more or less, but do not prevent fair yields. The study was made as complete as possible within the limited time, life histories were obtained for most of the pests, and remedies elaborated. The results are now in manuscript and will later appear as a bulletin.

The most destructive pest of sweet potatoes apparently is the stem borer (*Omphisa anastomosalis*), a recent introduction from China. It bores into the stems and kills many plants. It sometimes gets into the potato, in which case the damage is even more serious. It is not much parasitized and is quite common in sweet-potato fields. It would be difficult to control artificially. The leaves of the sweet potato are mined by the larvæ of the tineid moth (*Bedellia orchilella*), and probably by other species of this genus, but this pest is fairly well kept in check by chalcid parasites. The hornworm (larva of the sphinx moth, *Phlegethontius convoluli*) is quite common but not often very injurious; cutworms are said to attack the sweet potato; and there are two leaf rollers (*Phlyctænia despecta* and *Amorbia emigratella*) which damage the foliage to some extent. The common sweet-potato weevil (*Cylas formicarius*) has at times been a very destructive pest and one difficult to control. It breeds in the stems of the common shore plant (*Ipomœa pes-capræ*), and will always be a menace to the cultivation of sweet potatoes, although actual instances of its infesting sweet-potato fields are few. Another weevil, the West Indian scarabee (*Cryptorynchus batatæ*), is also common in the tuber or rootstock of the sweet potato and at times greatly damages the crop. Among the minor pests may be mentioned the leaf hoppers *Nesosydne ipomœicola* and *Oloha ipomœa*, *Plusia chalcites*, an undetermined Pseudococcus, the Japanese beetle, and a species of Saissetia.

Considerable time has been spent in studying Coccidæ—a group of extreme economic importance in these islands—but no report can be offered on this work. An addition was made to the list of Hawaiian Coccidæ in recording the presence of *Geococcus radicum* Green on roots of mango, koa, and nut grass. The insect was described and figured anew by the writer.[1]

[1] Proc. Hawaiian Ent. Soc., 2 (1910), No. 3, p. 108.

A FIVE-YEAR-OLD AVOCADO TREE, TOP WORKED TO A SELECTED VARIETY BY BUDDING.

REPORT OF THE HORTICULTURIST.

By J. E. Higgins.

The work of this department for the fiscal year dealt chiefly with the avocado, mango, papaya, and citrus fruits. Minor attention has been given to the sweet potato and to a considerable number of miscellaneous subjects which demand recognition in the present stage of Hawaii's horticultural development.

AVOCADO.

The work with avocados during the year may be classified chiefly under four subjects, as follows: Propagation, insect control, disease control, and study of varieties.

PROPAGATION.

Substantial progress has been made in devising means for the successful budding of the avocado. Because of the lack of young nursery stock most of the trials have been in topworking of orchard trees. Plate I shows a tree in the experimental orchard topworked to a valuable variety by means of budding.

The greatest difficulty in budding appears to be not in getting the buds to unite with the stock, but in forcing them into growth. The sap of the avocado oozes out from incisions in the bark, and in budding this characteristic aggravates the difficulties. The sap finds an exit through the T incision, evaporates, and leaves here a crystalline deposit which frequently covers the whole bud, and sometimes the whole bud shield. This is particularly likely to occur before a union has been effected, although it may occur long after. It has been found possible largely to control this trouble, during the period when union is being effected, by wrapping the whole of the stock, in the region of the incision, and thus preventing evaporation.

When a bud has become united to the stock it has proved inadvisable to lop the stock immediately, as is done with citrus and some other budded stocks. The wood is often so brittle in the young portion, where the bud is inserted, as to prohibit successful lopping. If partly cut, it will snap off completely. If a stock is completely cut off, it is likely to die back to the bud and below it before the latter has started into growth.

To overcome these difficulties it has been found advisable to girdle the stock completely, or partly, at a point several inches above the bud, being careful to remove only the bark, so that the upper portion

will not be destroyed. Mr. Holt, who has done most of the actual manipulation of the buds under the direction of the horticulturist is continuing the work with a view of overcoming more completely some of the difficulties which have made the budding of avocados somewhat discouraging.

Inarching is being successfully used for certain types of propagation. It is quite easy to effect a union of scion and stock by this method, which presents a very ready means of bringing seedling varieties into early bearing by placing them on old trees. This may prove to be one of the best means of testing out seedlings whose characters it may be desired to determine, either for practical or scientific purposes.

Some success has been had in growing avocados from cuttings. It has frequently been found in the station experience that avocado cuttings readily form a callus, but do not strike root. The method which has proved partly successful in causing the formation of roots during the past winter consists in packing the cuttings in moist sphagnum moss for several weeks before placing them in the propagating bench. Thus far well-matured wood with gray bark has proved most promising in this work. If cuttings can be made to root readily there are occasions when this means of propagation could be advantageously used.

INSECT CONTROL.

The two chief insect pests of the avocado in the station orchards during the year have been the avocado mealy bug (*Pseudococcus nipæ*) and the larva of the tortricid moth (*Amorbia emigratella*). The latter has caused considerable damage to foliage in the station orchard and to the fruit in gardens of the city. The larva wraps itself up in the young leaves, sometimes sewing together the terminal leaves while opening. It inhabits this place until the food supply is somewhat reduced and then proceeds to another similar locality. Because its attack is upon the very newest growth it is not as easy to control by arsenical poisons as would otherwise be the case. However, frequent spraying with arsenate of lead has considerably reduced the numbers of these insects.

The avocado mealy bug for some years has not required much attention to keep it under control in the station orchard. Practically no spraying has been done for two or three years, and only an occasional tree has been fumigated. There are always some insects of this species in the orchard, but they do not appear to become a serious pest, probably being held in control by ladybirds. It is aimed to foster these by planting, every rainy season, a cover crop of cowpeas, jack beans, or some similar legume, which is subject to the attacks of aphides. These aphides do not disturb the avocado, but multiply

in the legumes and furnish an abundant food supply for numerous species of ladybirds. After this food supply has been cut off, these natural enemies of the mealy bug turn their exclusive attention to the scale insects of the trees.

DISEASE CONTROL.

A fungus disease of the avocado, probably a species of Glœosporium, has done much damage in many parts of the Territory; in fact, no district has been visited by the horticulturist in which this disease has not been very prevalent. It attacks the leaves, causing them to become a rusty brown color, and frequently causing them to fall prematurely. It also causes the dying back of the twigs and branches and often results in the total destruction of the tree. During the past season, flowers were noticed destroyed apparently by this fungus, the destruction extending into the new wood. When the vitality of the wood has been reduced, it becomes an attractive place for borers.

Work has been begun to test the efficiency of four leading fungicides in the control of this disease. With these fungicides, arsenical poisons have been included, when possible, as a means of destroying the Amorbia mentioned above. The remedies being tried are: Bordeaux mixture with arsenate of lead (6–6–50 formula); resin lime mixture with Bordeaux (formula, 2 gallons resin lime stock to 48 gallons Bordeaux dilute); self-boiled lime-sulphur wash (6–6–50 formula) with arsenate of lead; and commercial lime-sulphur (formula 1–30), with arsenate of lead. It is too early to look for marked results from the use of these fungicides, since the work has been in progress only a short time. It can be said, however, that none of the remedies has produced any serious foliage injury.

VARIETIES.

Mr. Hunn, the assistant horticulturist, has made careful studies of a large number of varieties of avocados for the purpose of ascertaining their merits for commercial or home production. Many very excellent midseason varieties have been found. These, unfortunately, are not the best adapted to commercial growing, because they would reach the mainland when the markets were overstocked with many kinds of Temperate Zone and subtropical fruits. There is, however, a sale for such in limited quantities at high prices even at that season. First-class avocados in sound market condition will sell at that season of the year (June, July, and August) at $2 to $2.50 per dozen in the San Francisco market. The extra early varieties, which could be placed in mainland markets before the 1st of

June, and the extra late varieties which would be marketable after the 1st of November, could be sold in large quantities, as the demand for fresh fruit is better at that time. The four varieties following are of particular merit from one or another of the points of view indicated above:

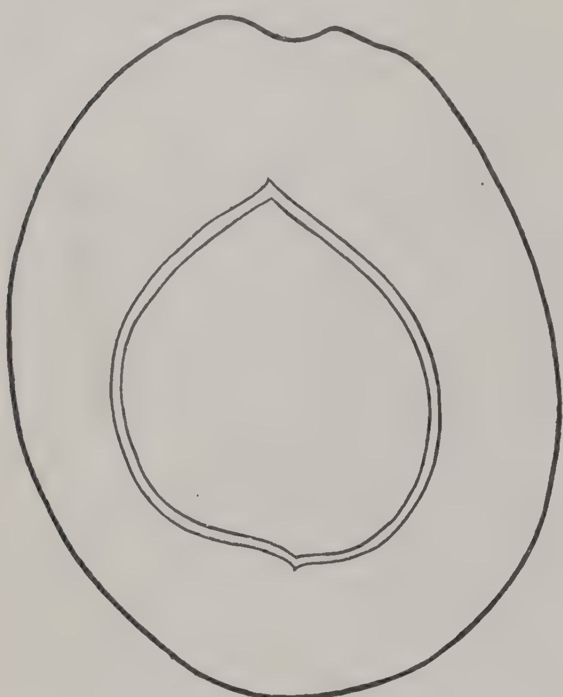

FIG. 1.—Form of fruit and seed of avocado No. 149. About one-fourth natural size.

No. 149 (Fig. 1). About 20 years ago Admiral Beardsley, leaving Guatemala for Hawaii, carried with him a number of avocados for consumption on the way. He saved two seeds, wrapping them in cotton wool and packing them in ice. Arriving in Honolulu, he gave one seed to Judge Wiedeman and the other to Mrs. E. K. Wilder. The former was planted at 1402 Punahou Street, now occupied by "The McDonald," and although both seeds grew, this one is far superior in quality and blooms earlier.

Form roundish to spherical; size medium to medium large; cavity small, shallow, and flaring; stem somewhat slender and very long, varying from 6 to 15 inches in length; surface undulating, very hard; coriaceous and markedly pitted; color dark olive green to purple, with small, very abundant, irregular-shaped yellowish dots; apex a mere dot, slightly depressed; skin very thick and woody, separating freely from the pulp; flesh yellow in color, running into green at the skin, fine grained, oily and somewhat buttery, 75 per cent of fruit; seed fairly large, roundish conical, just a trifle loose in the cavity; flavor rich and nutty. Season July to January.

The tree is quite vigorous, but tends to grow upward rather than to branch out, probably due to confinement. This pear is especially noteworthy, since it will keep for a long time after being removed from the tree. Mr. G. P. Wilder reports that he has kept the fruit for two and one-half weeks after removal from the tree. The tree carried fruit over through the blossoming period of the following season. Height 40 feet, spread 20 feet.

Valuable as a late avocado. Its woody skin should make it a good shipper.

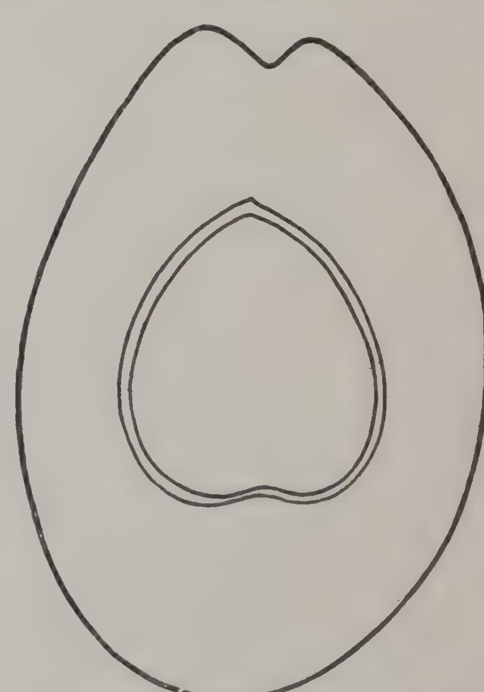

FIG. 2.—Form of fruit and seed of Moanalua avocado. About one-fourth natural size.

MOANALUA (Fig. 2). A chance seedling 19 years of age growing on the estate of Hon. S. M. Damon, Moanalua.

Form pyriform; size small to medium; cavity flaring, deep; stem somewhat short, rather thick; surface undulating, hard, coriaceous, and slightly pitted; color dark green, with medium abundant, small, irregular-shaped yellow-

ish dots; apex a mere dot; skin medium thick, separating readily from the pulp; flesh yellowish in color, running into green at the rind, fine grained, melting and somewhat buttery, 70 per cent of the fruit; seed medium large, conical, fitting tightly in the seed cavity; flavor rich and nutty. Season July to September.

The tree is very vigorous. Height 30 feet, spread 25 feet.

No. 150 (Fig. 3). A chance seedling whose origin and age are unknown, growing near the residence of Charles Renear, Emma Street.

Form pyriform; size small to medium; cavity shallow and somewhat rounded; stem short and medium thick; surface undulating, medium hard, coriaceous, slightly pitted; color green, with reticulate-like markings, with medium large somewhat circular yellowish dots; apex a mere dot; skin very thin, separating readily from the pulp; flesh yellow, melting, but a trifle watery, 70 per cent of the fruit; seed medium large, conical, fitting loosely into the cavity; flavor pleasant. Season middle of May to July.

Valuable because of its earliness. Height 30 feet, spread 20 feet.

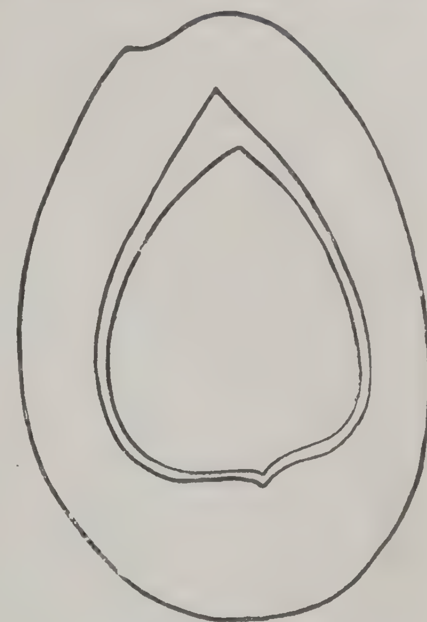

Fig. 3.—Form of fruit and seed of avocado No. 150. About one-fourth natural size.

No. 145 (Fig. 4). A chance seedling about 15 years of age; origin unknown.

Form pyriform; size small to medium; cavity shallow and somewhat abrupt; stem medium long and quite thick; surface undulating, hard, coriaceous, and slightly pitted and mottled; color green, with small, very abundant yellowish dots; apex a depressed dot; skin quite thin, separating fairly well from the pulp; flesh yellow, running into green at the rind, fine grained, oily, and somewhat buttery, 60 per cent of the fruit; seed very large, conical, fitting loosely in the cavity; flavor rich and nutty. Season September to January.

This tree is very vigorous and symmetrical. Height 25 feet, spread 25 feet.

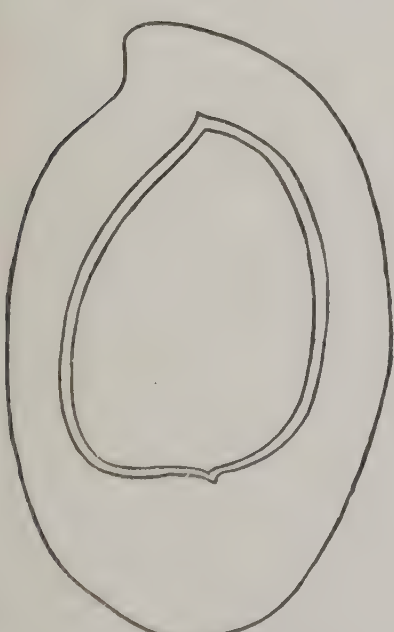

Fig. 4.—Form of fruit and seed of avocado No. 145. About one-fourth natural size.

FERTILIZER TRIALS.

The station orchard, consisting of miscellaneous varieties and many seedlings, makes it impossible to conduct an exact fertilizer experiment, but certain sections of the orchard have been chosen which apparently furnish sufficiently uniform conditions for some simple trials of fertilizers. It is hoped that these tests, conducted in cooperation with the chemical division of the station, will point the way to more definite and accurate experiments when uniform conditions can be attained. From our observations there is some evidence that the excessive use of nitrogenous fertilizers may tend to produce a fibrous fruit.

MISCELLANEOUS STUDIES.

Some studies have been made of the root system of the avocado. Attention has also been devoted to pruning, girdling, and other orchard operations.

MANGO.

PROPAGATION.

The propagation work with the mango has been continued along the lines outlined in previous reports and bulletins. Good use has been made of the method of shield budding the mango.[1] By this means a still larger number of new varieties have been worked in the trial orchard. Quite a number of potted trees have been taken to the orchard and have afforded inarches on some of the older seedling trees. A marked example of the results which may be obtained by this method has come into the station experience during the year. In December, 1908, an Indian variety, Brindabani, was thus grafted upon a strong seedling in the orchard. At the present writing, 18 months later, the new variety is bearing fruits nearly fully matured, others in various stages of development, and also flowers.

TRANSPLANTING.

Opportunity has been afforded for still further testing the possibilities of transplanting large nursery trees. Quite a number of 4 and 5 year old trees were taken up from the nursery and removed to the orchard, in part to test this matter, since it has frequently been stated that mango trees are difficult to transplant. All the trees were severely cut back, leaving only a trunk about $2\frac{1}{2}$ feet above the crown. The transplanting was done in the autumn and early winter, at a time when the trees were not flushing. Some of the trees were removed with naked roots and carefully taken at once to the orchard. Others were taken out with a ball of soil and planted immediately. Still another lot, which had been dug up 15 days previously and had been carefully " heeled in," were planted beside the others. A fourth lot, which had been treated in the same manner as lot 3 except that the naked roots were exposed to the air for an hour or two, was also planted. It has not been possible to detect any difference in the vigor of growth of any of the above lots, all trees having lived and made a good growth.

Mr. E. C. Smith, of Pearl City, Oahu, reports that he at one time removed a mango tree which had been bearing, and though severely cut back even the next year's crop was not lost. It appears, there-

[1] Hawaii Sta. Bul. 20.

fore, that if mango trees are transplanted when not in flush and are severely cut back a large degree of success can be expected in transplanting.

The above results of trials, together with the methods of budding the mango referred to, would seem to place beyond doubt the growing of the mango as nursery stock on a commercial scale

ROOT SYSTEM.

Studies have been made of the root system of the mango by sluicing away the soil and removing the tree with its main roots intact.

INSECT CONTROL.

It has been found necessary to fumigate a few trees in the mango orchard for the destruction of the scale (*Phenacaspis eugeniæ*) and also a few for the Florida red scale (*Chrysomphalus aonidum*). When the mango tree is not flushing it can be fumigated with hydrocyanic-acid gas in doses equal to those used on citrus trees without injury to the foliage.

A red-banded thrips (*Heliothrips rubrocinctus*) should be mentioned in this connection. These were found in large numbers on young mango seedlings in the greenhouse, and were causing very serious damage. They were referred to the station entomologist, who kindly had them identified as above. Those who are starting mango plants in greenhouses or in a sheltered place should be on the lookout for these pests. They may be distinguished as small, rather wedge-shaped bodies, very beautifully marked with red bands. It has not been found difficult to destroy them by dusting the plants with finely powdered sulphur after they have first been sprayed with water so as to retain the powder.

The species of Amorbia referred to elsewhere as a pest of the avocado has also proved destructive to the mango flowers and to some degree to the young leaves. Arsenate of lead has been found effective in destroying the larvæ.

The large carpenter bee (*Xylocopa æneipennis*) did considerable damage to young mango buds in the propagation experiments until its work was discovered and prevented. The bee seems to find an inviting place for boring just above the bud on the bud shield, and in many instances bored through the shield into the old wood of the stock, causing injury and sometimes destruction to the bud. It has been found easy to control this injury by placing grafting wax in all the incisions, leaving only the bud and a small portion of the shield exposed. This should be done when the bandage is removed, if injury of this kind is experienced.

DISEASE CONTROL.

The fungus (*Glœosporium mangiferæ*) does great injury to the mango crop in Hawaii, destroying the flowers and much of the fruit. It has been stated in earlier reports that this disease can be held in control by Bordeaux mixture. Experiments, however, have been undertaken with other fungicides for the control of this fungus. The same series of trials, as outlined elsewhere for the control of the diseases of the avocado, is in progress in the mango orchard.

VARIETIES.

There is now quite a large number of varieties in the station orchard. Some of these are introduced varieties from India and elsewhere, and others are valuable local seedlings. The list of varieties now growing at the station is as follows:

Alphonse, Accession Nos. 1072, 1158, 2014, 2101.

Douglas Bennett's Alphonse, Accession Nos. 278, 1161, 1370, 1371, 1926, 1933.

Ameeri, Accession No. 2100.

Arbuthnot, Accession No. 1943.

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PAPAYAS.

MONŒCIOUS AND DIŒCIOUS TYPES.

Investigations have been begun with papayas which are of interest because of their bearing upon theories of plant breeding and also because of their practical aspect. It is a well-known fact that papayas are extremely uncertain in the reproduction of their characters. Selection has been practiced to a considerable degree by the growers of this fruit, but seeds from the best fruit are liable to produce trees of very indifferent character. The reasons for this may be suggested by a study of the different types of the papaya. There are two extreme types and several intermediate forms. First, there is the strictly diœcious type. In this, the fruit-bearing tree produces pistillate flowers only. The staminate, or "male," tree produces staminate flowers almost exclusively but with an occasional perfect flower which is capable of producing fruit. Most of the staminate flowers have a rudimentary ovary and style, but are without any stigma, and are utterly incapable of fruit production. The fruit of the pistillate tree of this type is usually ovoid or more or less rotund in shape.

The second type is monœcious. Every tree produces fruit. The trees produce two forms of flowers; first, a perfect flower, and, second, a staminate flower. In the axil of each leaf there is usually a small flower cluster, only a few inches in length, which contains at least one perfect flower and one or more staminate ones. This perfect flower is quite different in shape from the pistillate flower of the diœcious type. Its pistil is much more elongated, being almost cylindrical throughout a portion of its length. The stamens are usually situated on the inner walls of the petals, about midway of their length, with the anthers surrounding the lobes of the stigma. The fruit of this type differs from the fruit of the diœcious tree in the same way as the pistils. The fruit of this monœcious type is usually elongated, and is generally spoken of as the "long" papaya.

Between these two types, the one almost completely diœcious and the other monœcious, there are many intermediate forms which may have arisen through the crossing of these two. For example, there are in the station collection trees which produce three types of flowers, namely, staminate flowers and two forms of perfect flowers. The one form of perfect flower corresponds precisely with the per-

fect flowers of the monœcious type, spoken of above. The other perfect flower has an ovary in shape like that of the pistillate flower of the diœcious type, and produces a fruit more nearly resembling this type. Its stamens, however, are variously located; they may be found at times arising from the base of the petals; or at times the anthers are attached to the lobes of the ovary, the latter condition usually resulting in a deeply furrowed or distorted fruit. One tree in the station collection produces only staminate flowers, but is peculiar in the fact that these flowers are borne close to the stem and in the axils of the leaves, while staminate trees of the ordinary diœcious type produce their flowers in long pendant clusters.

BREEDING PROBLEMS.

What is the bearing of these facts to a practical plant breeder who may wish to produce a papaya of a good variety whose characters will be more or less stable in reproduction? Suppose that the diœcious type is used in selection, as has been the case usually. Seed from this fruit will necessarily be a cross of two individuals. The characters of the female plant are known, but those of the male plant are utterly unknown. The parent stock from which both came may be known, but since there is wide variation in the fruit of two pistillate trees from the same stock it is reasonable to suppose that there will be the same wide variation in the male or staminate trees. The variation between the pistillate trees can easily be determined because their fruits are in evidence and can be tested; but the characters which are inherent in the male or staminate tree, and which will be transmitted by it to its progeny, can be determined only through the long process of actual hand-pollination, the sowing of the seed thus produced, and the testing of the fruit. Even then, what portion of its excellent or indifferent qualities it may have inherited from its male parent can not be known. Furthermore, the difficulty becomes aggravated by the fact that papaya trees usually degenerate after a very few years. At least, pistillate trees usually fail to produce good fruit after a few years of growth, although they may continue to produce indifferent fruit for many years. Therefore, even if the inherent characters of the male or staminate tree could be determined with reasonable accuracy, before any such determination could be made the tree would have become too old to be in a reliable state of virility, if it degenerates as rapidly as the pistillate tree. It therefore appears reasonable to suppose that the process of producing a stable variety of good qualities by the use of this diœcious type would be extremely long and tedious. The hope, therefore, must lie in the use of the monœcious type. Here it is possible to select an individual of known qualities. This may be used as the sole parent stock, or may be combined with another parent of known

qualities. Of course, either may at the start be of uncertain reproducing power. That is to say, what mixtures of blood there may be in the individual at the start may not be known; but through repeated selections and the elimination of undesirable characters, it should be possible to produce a reasonably stable variety, provided, of course, that the stock is kept pure by constantly avoiding cross-pollinations, a process which is necessary in all plants reproduced by seed and whose flowers are subject to accidental cross-pollination.

A further practical difficulty in the use of the diœcious type, from the standpoint of the papaya grower, as well as the breeder, is the fact that a very large proportion of the trees from any given lot of seed are liable to be staminate, or males, and therefore useless, only a few trees being necessary to pollinate all the pistillate trees. It is impossible to distinguish the staminate from the pistillate trees in the early stages of their development. Various theories have been advanced to distinguish these two sexes before the trees have flowered, and it has been reported that staminate trees have been caused to produce pistils and fruits by beheading them. None of these means, however, has proved to be successful from a practical standpoint. Therefore, in any papaya orchard planted with the diœcious type, a very large percentage of the trees must be cut out after they have grown almost to maturity, resulting in unevenness and irregularity in the orchard and much loss of time and space. For this reason, together with the difficulties of breeding, the diœcious type will likely be largely eliminated.

Returning to the subject of papaya breeding, it is not yet known what the result will be from crossing the pistillate tree of the diœcious type with pollen from a tree of known character of the monœcious type. As has been indicated above, there are several intermediate forms which appear to be the result of crossing the monœcious and the diœcious types; but, apparently, there is no definite knowledge on this point. These intermediates may have resulted from the accidental crossing of the monœcious type with pollen from the staminate tree of the diœcious type. It may be possible to make some of these crosses without giving rise to an undue number of male or staminate trees.

This work which is only in its incipiency offers a wide and interesting field for investigation.

CITRUS FRUITS.

INSECT CONTROL.

No new problems have been undertaken with citrus fruits. The orchard is being maintained and has afforded opportunity for the further testing of fumigation with hydrocyanic-acid gas for the con-

trol of the mealy bug (*Pseudococcus filamentosus*) and other scale insects. This method of control has proved the most effective means which has yet been tried. It is extremely difficult to control *P. filamentosus* because it is so vigilantly attended by ants. It has been found possible to destroy the insects on the trees by fumigation if the soil is removed from the crown so as to expose the insects to the gas. Reinfestation, however, takes place more rapidly than in the case of the Florida red scale (*Chrysomphalus aonidum*) and the purple scale (*Lepidosaphes beckii*).

The caterpillar (*Amorbia emigratella*), referred to as a pest of mango and avocado, has required considerable attention. After consultation with the entomologist, treatment was begun with arsenate of lead. Because of the habit of this insect, in wrapping itself up in the newest growth, it becomes difficult to poison it with arsenical sprays. The spraying was repeated several times. The insect now appears to be fairly well under control.

NEW VARIETIES.

Several new varieties of oranges, pomelos, and lemons have been introduced during the year. A number of the newer Florida pomelos have been budded into the station orchards and nurseries. The station agronomist, Mr. F. G. Krauss, while traveling in Japan and China, collected some of the best pomelos of those countries, including the famous Amoy variety. Bud wood was brought back to Hawaii, and some of it arrived in fair condition. Buds were inserted in a number of stocks at the station, but none has succeeded. The buds "took," and a few started into growth but afterwards failed.

A number of citrus varieties have been received from Mr. Gerrit P. Wilder while traveling through the Orient and southern Europe. These have been worked into the nursery by both budding and grafting and are making good progress.

SWEET POTATOES.

In a bulletin of this station,[1] attention was called to the possibility of a profitable industry in the shipping of sweet potatoes from Hawaii to the mainland of the United States and Canada during the season when the market there is practically bare, because the home-grown product is out of season. All these markets are accustomed to the yellow variety, known on the Pacific coast as Merced Sweet. This local name has arisen from the fact that Merced is the center of the most successful sweet-potato cultivation. The variety is that usually known in the East as the Jersey Sweet. It was also stated in the

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[1] Hawaii Sta. Bul. 14.

bulletin referred to that the red varieties commonly grown in Hawaii are unfamiliar to those markets. This left the question open as to whether Hawaiian sweet potatoes of the ordinary varieties would find a ready sale on the mainland.

This matter has been tested by the growing of a number of varieties and the marketing of the same in San Francisco. The first two shipments included several red sorts as well as the Merced. All varieties sold readily at 8 cents per pound. Later reports, however, brought out the fact that the dealers found the consumers prejudiced against the red color and refused to buy them. It would seem to be unwise for Hawaiian shippers to attempt to break down this prejudice, and attention should be given to the growing of the Merced variety, with which the market is familiar. Roots of this variety are being distributed by the station.

These trial shipments confirm the earlier belief that sweet potatoes of suitable varieties will bring high prices when the California product is out of season.

It seems hardly necessary to state that 8 cents per pound should not be expected on large shipments. The commission house which handled these trial lots advised the station as follows:

"If you can succeed in producing the yellow variety of medium to large size, we are confident they can be distributed here during our late spring and early summer season so as to make them quite profitable to you. By this we mean from 4 cents to 5 cents per pound with a possibility of higher prices for a portion of them."

The season of shipping is important. California sweet potatoes are out of season from about May 15 to August 1. This is the period during which Hawaiian-grown sweet potatoes should arrive. In some years it may be found possible to put them in a little earlier.

MISCELLANEOUS NOTES.

Quite a large amount of miscellaneous work presents itself from time to time, and miscellaneous plants of different species demand some attention. A few of these may be mentioned.

GARCINIA MANGOSTANA.

The mangosteen has one or two bearing trees to represent it in Hawaii. Two fruits, which represented half the crop of one of these trees, were secured a year or two ago. One of the two fruits contained a seed, which was planted and has made rather an indifferent growth, but has done better than plants which have been introduced in Wardian cases.

There are one or two other species of Garcinia in Hawaii which appear to do well. It has seemed probable that the mangosteen might do better in Hawaii if budded on other stocks. Mr. E. W.

Jordan secured bud wood of the mangosteen from Mr. Francis Gay, of Kauai, and the writer, in cooperation with Mr. Jordan, placed buds of these on the *Garcinia xanthochymus*, known locally as the "African mangosteen." This work was performed only a few weeks previous to the present writing, and it is therefore too early to know whether any successful results will arise.

CARISSA ARDUINA.

Carissa arduina (Ac. No. 1764, S. P. I. No. 11734), which is a South African fruiting shrub, was introduced from the Section of Seed and Plant Introduction of the Department of Agriculture in the year 1905 under the number indicated above. The four plants received at that time have all made a vigorous growth, but have exhibited decided differences in character. Two of the plants have proved heavy producers and two have been rather shy bearers. Plate II, figure 1, shows one of these trees in fruit.

The shrub is useful as a hedge plant because of its dense growth and its strong thorns, which render it practically impassable, and also for its very beautiful red fruits, which are about the size of a plum. The latter may be eaten from the hand or may be used in the manufacture of jellies.

Selections are being made of the best fruits from the two best trees. About 2,000 plants are now in the greenhouses and will be ready for distribution within a few months. There remains a large crop of fruit, affording the opportunity for still larger propagation and distribution. It is believed that the plant will be useful as a hedge to surround fruit gardens which are subject to the attacks of nocturnal visitors.

After the plants have become well established in the propagating houses they appear to be free from all serious insect attacks in Hawaii. They are subject to the attacks of the scale, *Saissetia hemisphærica;* but this is so successfully parasitized in Hawaii by *Scutellista cyanea* and other parasites that it has not proved a pest on Carissa.

LITCHI (NEPHELIUM LITCHI).

A number of the plants of this species, introduced from China in 1908, have made a fair growth, although severely attacked by the Japanese beetle and by the scale (*Saissetia nigra*). The latter can readily be controlled by fumigation, and it is not believed that the Japanese beetle will prove a serious pest after the trees have grown to large size. The seedling litchis that are growing in various parts of Honolulu are not seriously attacked by this pest.

The litchi, being a slow grower and requiring usually from 15 to 20 years to come into bearing, when grown from seed in Hawaii, it

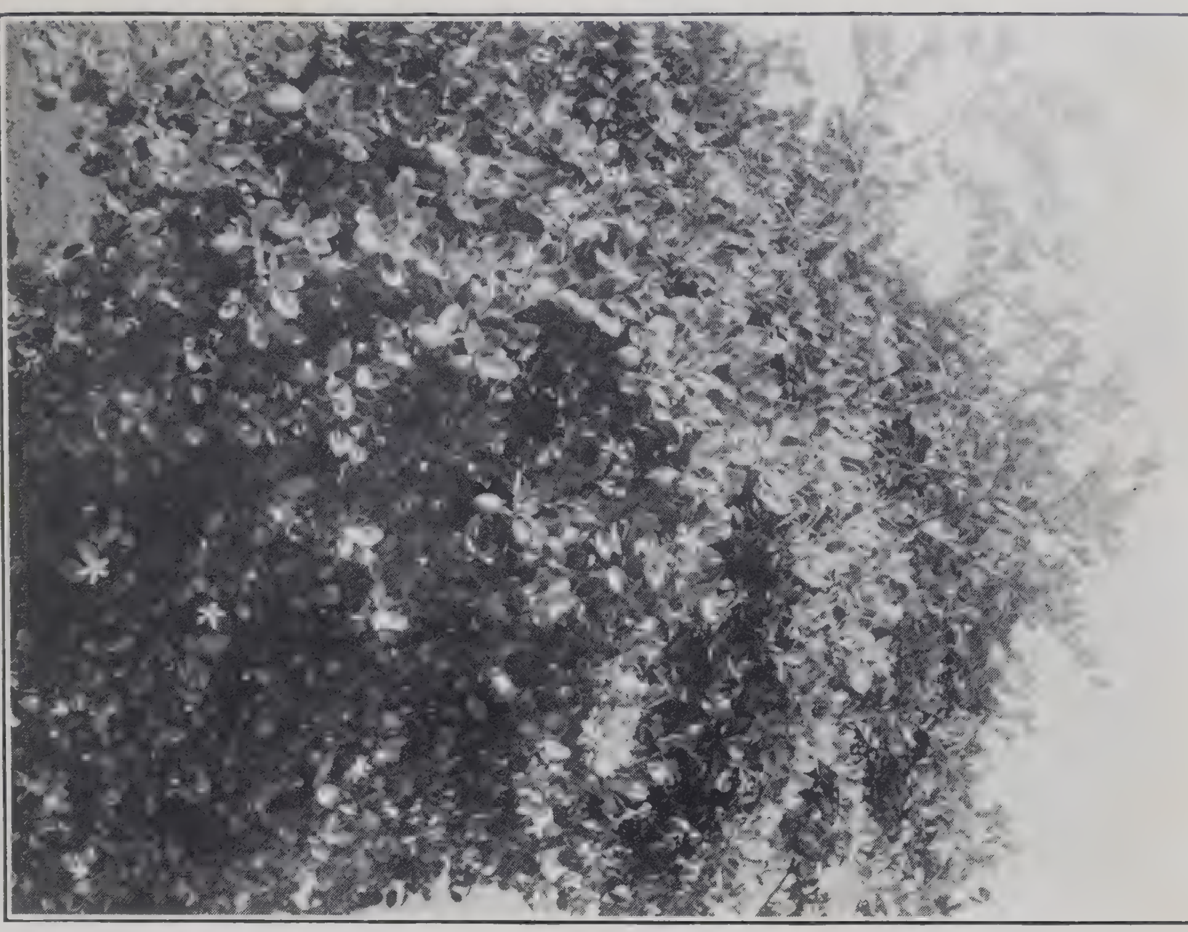

FIG. 1.—CARISSA ARDUINA, A VALUABLE FRUIT AND HEDGE PLANT.

FIG. 2.—PIGEON PEAS AS A WINDBREAK FOR NURSERY STOCK.

has been thought desirable to attempt the growth of this tree on the more vigorous growing stock of the longan (*Nephelium longana*). Attempts are now being made to graft scions of these imported varieties on seedling longans by the inarching method.

DECIDUOUS FRUITS.

As stated in previous reports, the Parker ranch has undertaken rather extensive experiments in the growing of deciduous fruits and grapes. In these experiments the station has taken a considerable interest and has cooperated so far as possible. In February, 1910, the horticulturist again visited the chief of these plantings at Waiki, on the island of Hawaii, at an elevation of about 4,500 feet. Instruction was given in pruning, insect control, and the general care of the orchards, and observation was made of the progress of the different kinds of fruits being grown. This being the winter season, it was impossible to judge of the fruits themselves, except in the case of a few apples which had been kept through the winter. These were of good size, and those that were not withered by exposure to the air were crisp and of good flavor. Apples have made a very satisfactory growth, except those planted the previous season, which was one of unusual drought. Established trees seemed to do well, notwithstanding the prolonged dry weather. Peach trees also made a satisfactory showing and were reported to have produced good fruit. They were well supplied with fruit buds. Cherries have not succeeded, and plums and pears can not yet be said to have proved a success. Grapes of several varieties, including the Tokay and the Muscat, have made good growth and are reported to have produced fruit in 1909. In general, it may be said that the outlook is promising for the production of apples, peaches, and grapes in this locality.

TREE TANGLEFOOT.

This sticky substance has been used on the deciduous plantings, as well as on the station trees, for the purpose of preventing ants, cutworms, and other injurious insects from ascending the trees. Under some conditions it has proved quite effective if the surface is kept renewed by repeated agitations, or combings. A serious result appears to have followed the use of this remedy at the Waiki orchards on peach trees. It had been applied directly to the bark of the trunk and had remained for many months. Wherever it was found remaining upon the peach trees they were dead. Examination of the bark of the trunk under this sticky preparation revealed injury of the tissue and a discoloration which extended completely around the trunk. This remedy has been applied to the bark of a number of trees at the experiment station without any apparent injurious effects, but

it has not been so applied to peach trees. It is, therefore, recommended that precaution be taken in its use, and that in the case of peach trees, particularly, it should not be applied directly to the bark. A broad bandage, made of cheap cotton dipped in hot paraffin, may be wound spirally around the trunk of the tree and tied at the top by splitting into two parts like a surgeon's bandage. To this the sticky substance may be applied without injury. If the cotton is not too strong there will be little danger of girdling.

PIGEON PEA.

The pigeon pea (*Cajanus indicus*) is being tested as a temporary wind-break and as a permanent wind-break for nursery stock. In two or three months from seed, it affords considerable protection to small growth, and in six or seven months attains a height of 6 feet, and thus makes a good wind-break for young citrus, avocado, and mango seedlings. For this purpose it is planted quite close in the row, the plants standing only 3 or 4 inches apart. In citrus nurseries, the rows of these fruit trees are being tried at 6 feet apart, and a row of pigeon pea is being planted midway between the citrus. Where land is cheap, it would be better to increase the distance between the rows. By this means the wind-break could remain as long as the trees might be in the nursery. Plate II, figure 2, shows the pigeon pea protecting young citrus seedlings.

RATTAN PALMS.

Several species of this palm, Dæmonorops, have been introduced from Java. About 200 of these palms have been distributed in different parts of Hawaii where it was thought they would be most likely to succeed. These plants afford a fiber which is used in the shipping of tobacco, and if successful in Hawaii should be a valuable aid to the tobacco industry.

BOUGAINVILLÆA DISEASE.

A disease of the bougainvillæa has been observed during the year on both the species *B. spectabilis* and the species *B. refulgens*. This is a sort of crown rot which causes the decay of the bark and wood near the ground. A large vine of *B. spectabilis* was treated by the removal of the dead bark and the washing of the wound with carbolic acid and water, after which paint was applied. The plant appears to be regaining vigor.

REPORT OF THE CHEMIST.

By W. P. Kelley.

During the past year the chemical department has been engaged mainly in soil and fertilizer investigations along the lines suggested in the previous report. In addition, some attention has been given to a study of the composition of pineapples.

PINEAPPLE SOIL INVESTIGATIONS.

In the report for 1909 the writer pointed out some of the conditions that exist in the pineapple districts of Oahu and drew attention to their peculiarities. Investigations during the past year have further emphasized the necessity of a more intelligent management of these soils. Frequent requests by farmers for assistance and advice, together with numerous observations by the writer, have led to the conviction that the time has already arrived when special efforts must be put forth by the farmer if profitable yields of pineapples are to be maintained. The pineapple industry, important as it has become, is still in its infancy in Hawaii, and while continuing to hold out great promise, failure, or only partial success, has resulted in numerous instances. This fact, together with the scientific interest that naturally arises in connection with soils of such abnormal characteristics, justifies a thorough study of all the factors that influence the ultimate fertility of this land.

In numerous instances the application of various fertilizers in liberal quantities has not given satisfactory returns, and an increasing number of planters are realizing that something more than the addition of available plant food is demanded in their fields. The lack of drainage is evident, and in many instances a poor mechanical soil condition is apparent. With satisfactory yields on virgin soil the growers in many instances have failed to adequately appreciate the importance of maintaining what is called "condition" in the soil. In the main the land is under short-term lease, and the principal idea from the beginning of this industry has been to get out of the land a maximum crop at a minimum of cost, with little concern for the ultimate maintenance of the soil.

The work of this department in this connection has been directed along lines which are calculated to show the fallacies of the prevailing system and to secure a scientific basis for rational and permanent conservation of the soil. Looking to this end a series of field and laboratory investigations are under way which have already

resulted in data of scientific interest and of practical value, and when completed ought to enable the farmer to adjust his farm management so as to secure both profit from his efforts and a perpetuation of his business.

It is not considered necessary at this time to detail these investigations, as it is hoped to present this work in its entirety later in the year. The work is being directed toward a study of the effects of aeration, and the chemical and physical changes induced by continued cultivation are being studied in a systematic way. The nitrifying power of the soils, the decomposition of humus, and the physical and biological changes which develop at remarkable rates under the conditions that prevail are being given due consideration.

On Oahu, as previously pointed out,[1] the pineapple soils may be roughly classified as manganiferous and nonmanganiferous. The former, on account of their extreme abnormality, have received considerable attention. The extent of the black manganiferous soil is considerably greater than had been anticipated, and comprises an important part of the pineapple sections of this island. While the areas that contain 4 or more per cent of manganese are ill suited to pineapple growth, the results already obtained indicate that the areas which contain an intermediate percentage of this element may, by the use of suitable fertilizers, be cultivated in pineapples with fair success. The physical properties of the manganiferous soils are superior to those of the nonmanganiferous areas, and drainage is much better on these areas. Consequently if the toxic effects of manganese can be overcome, their cultivation in pineapples will be more permanent.

In one of the manganiferous fields a fertilizer test has been under way for sometime, and while some of the plants made fairly normal growth during their first year's development, with the return of winter and its incident low temperatures the pineapples became yellow and abnormal. Some of the plants, however, have partially regained a normal appearance during the warm weather of the past few months, and are now in full fruit. The plants treated with dried blood or ammonium sulphate, superphosphate or reverted phosphate, and sulphate of potash have from the first greatly exceeded all others, and while the yields will not be entirely satisfactory it suggests a possible treatment for soils that contain more limited quantities of manganese. This soil appears to be greatly benefited by the application of soluble phosphates,[2] although the chemical analysis shows that it contains a rather high percentage of this substance. Not all forms of phosphates, however, are effective. Basic slag produces an increased tendency to a yellowing of the plants, and usually results in poorer yields than no treatment.

[1] Hawaii Sta. Press Bul. 23.

[2] See Agr. Gaz. N. S. Wales, 21 (1910), No. 5, pp. 437, 438.

The popular idea concerning the black manganiferous soils has been that they are sour and therefore in need of lime, but chemical analysis has proven this view to be incorrect, and the application of lime to these soils almost universally results in the development of a more intense yellow color in the plant and its subsequent failure to produce fruit. Basic slag is known to contain free lime, and it is likely that its injurious effect may be traceable to this substance.

A thorough study of the solubility of manganese and the influence of fertilizing substances on its solubility, the form in which the manganese exists in the soil and its relation to pineapple failure, and the influence brought about by the growth of pineapples on the form of the manganese in the soil, the influence of manganese on nitrification, and the physiological functions produced by this substance in the pineapple plant have received considerable attention.

Other crops have been grown on this type of soil in pot cultures with varying degrees of success. Some of these showed abnormal appearances, especially during the first two months of growth. Cereals seem especially sensitive to an excess of manganese. Legumes, although showing normal root tubercles, grew poorly. The lower leaves turned brown and fell away. Cotton and root crops seem less sensitive to this substance than other plants. In practically all plants grown in this type of soil peculiar color appearances were developed, indicating that it reacts in some way on the chlorophyll. In some instances the chlorophyll is destroyed; in others, etiolin or xanthophyll are developed instead of the green coloring matter.

These experiments will be repeated during the coming year and other crops tried and a further study of the physiological functions performed by manganese will be made.

In connection with the pineapple soil investigations on Oahu, some attention has been devoted to a study of the soils in pineapple sections of Maui, where different soil and climatic conditions prevail. Also, soil samples from Kula, the Parker ranch on Hawaii, and the Nahiku rubber district have been examined and some interesting results obtained.

RICE INVESTIGATIONS.

The fertilizer experiments with rice have been continued and some remarkably concordant results obtained. On account of the unreliability of a single year's test with fertilizers, the results of these experiments have not been published. It is customary with the Chinese rice growers in the islands to cultivate the same land in two crops of rice per annum, and where fertilizers are used generally only one application per annum, and that to the spring crop, is made. With the view of determining the residual effects on the fall crop from the spring application, the original plats in our experiments

have been divided into two parts, one of which received an application to the spring crop only, the other the same application to both crops. These experiments have now been carried through three crops and preparations are now under way for the fourth. It is intended to make this a continuous fertilizer experiment, with the view of determining whether it is possible by the use of fertilizers to obtain satisfactory yields under continuous cultivation of rice. A rotation experiment, involving the use of fertilizers, is also being made. In addition, a series of plats, to which different forms of nitrogenous fertilizers were applied, was laid out and some very interesting results obtained. Some experiments [1] were made previously, which indicated that ammonium sulphate is the most economical form of nitrogen for rice culture. A duplication of these results has been obtained. The yields from the plats treated with nitrate of soda have consistently fallen far short of the yields obtained from the use of ammonium sulphate. This observation has led to a detailed investigation of the absorption of nitrogen by the rice plant.

In pot cultures, under strict chemical control, various forms of nitrogen have been applied and some remarkably interesting results obtained. Where the rice has access to nitrates, only very poor growth has resulted; whereas ammonium compounds have resulted in vigorous development. These experiments are being repeated and will likely form the basis for a publication later in the year.

The original practice of applying fertilizers when the rice is about two-thirds grown gave rise to a study of the absorption of nutrients by the rice plant at its several stages of growth. This investigation was carried through two crops with concordant results, and the complete data bearing on this subject have been published.[2] From the results obtained it would seem that the practice of late applications of fertilizers should be abandoned. A large percentage of the substances absorbed from the soil is taken up by the rice plant during its early growth, and greater economy is sure to follow the application of fertilizers before planting than can be obtained from making the applications at the time usually practiced. In connection with this investigation it has been shown that the composition of the rice plant may be materially affected by the application of soluble fertilizers; especially is this fact noticeable during the early development of the plant.

FERTILIZER EXPERIMENTS WITH COTTON AND RUBBER.

As announced in the previous report, two fertilizer experiments have been made with cotton. These are being continued with prom-

[1] Hawaii Sta. Rpt. 1907, p. 83.

[2] Hawaii Sta. Bul. 21.

ising results. The yields of the first crop were, in some instances, more than three times as great on some of the fertilized plats as on the checks, and the appearance of the cotton at present indicates a similar influence in the second crop. The upland soils of the islands for the most part are lacking in available phosphates, due largely to the insoluble nature of the soil phosphates. Some attention has been given to a study of the solubility of phosphates in different types of soils,[1] and the results thus far obtained indicate that the phosphoric acid of the soil is largely combined with iron and alumina as basic phosphates, and hence insoluble.

A fertilizer experiment with rubber was also begun, but sufficient time has not elapsed to draw conclusions regarding the effects. Fertilizer experiments previously made with this crop were limited in number and no extensive results have been published. The slow growth of latex-bearing plants suggests the importance of a practical means of hastening the time of commercial tapping. In this experiment not only the increased growth of the trees is being measured, but the rate of latex flow and the percentage of rubber obtained therefrom will be noted. The soil on which this experiment is located is rich in humus, but inadequately aerated, as is shown by the fact that practically all the iron compounds therein are in a ferrous state, which can not be considered desirable at least. An increase in aeration, due to cultivation, has already been shown to produce an enormous increase in the growth of the rubber trees, and it is hoped at a later time to make a systematic study of this point.

THE COMPOSITION OF PINEAPPLES.

The composition of pineapples grown in other localities has been pointed out by several investigators. In a study of pineapples from Florida, the West Indies, Bahama, and Singapore, Munson and Tolman [2] showed that neither the variety nor the locality in which the fruit is grown exercises any marked influence on its sugar content, although the ratio between reducing sugars and sucrose in a given variety was shown to vary considerably. One pineapple of the Smooth Cayenne variety, for instance, was found to contain 3.17 per cent reducing sugars (calculated as invert sugar) and 7.51 per cent sucrose, while another of the same variety contained 9.75 per cent reducing sugars (calculated as invert sugar) and only 2.98 per cent sucrose. Some analyses were recorded which showed abnormally low percentages of sugar. This fruit was shipped a considerable distance before being analyzed, and irregularities in composition, as pointed

[1] Jour. Indus. and Engin. Chem., 2 (1910), No. 6, p. 277.

[2] U. S. Dept. Agr., Bur. Chem. Bul. 87, pp. 31–38; Jour. Amer. Chem. Soc., 25 (1903), No. 3, pp. 272–280.

out by the authors, may, in part, be traceable to differences in the degree of ripeness at the time of gathering.

Recently Blair and Wilson [1] made an extensive study of the composition of pineapples as affected by the use of fertilizers, and pointed out some interesting results. No extensive investigation of the composition of Hawaiian pineapples, however, has been published. although this fruit is generally conceded to be superior in quality to that grown in most localities.

The Smooth Cayenne is almost the only variety grown in Hawaii, and on account of inadequate shipping facilities and the prevalence of certain fungi a large percentage of these pineapples are used for canning purposes. The fruit for canning is allowed to ripen thoroughly in the field; that used for fresh fruit shipment, on the contrary, is usually gathered just before the true ripening process begins. Some shippers maintain, however, that pineapples one-third ripe may be shipped as satisfactorily as the green fruit.

For the purpose of determining some of the facts regarding the composition of pineapples as influenced by the stage of ripeness at which they are gathered, a number of analyses have been made. The methods employed in this work are essentially those given under the Official Methods for the Analysis of Fruits and Fruit Products.[2] The reducing sugars were determined by the volumetric Fehling solution method; sucrose by double polarization, acidity by direct titration with tenth-normal potassium hydrate with the aid of phenolphthalein. The acid of pineapples is largely citric, but is expressed here as sulphuric. The total hydrolyzable carbohydrates were determined by digesting for two hours 50 grams of the crushed fruit with strong hydrochloric acid (sp. gr. 1.125), cooling, neutralizing with caustic potash, completing to 250 cubic centimeters, and filtering. Reducing sugars in the filtrate were determined by the use of the volumetric Fehling solution method and the results expressed as invert sugar. Nitrogen was determined by the ordinary Kjehdahl method and the solids in the juice were calculated by the use of the tables of H. Ellion from the specific gravity of the juice. Fiber was determined by the usual method for fiber determination in feeds.

The fruits used in this investigation for the most part were gathered from the field by the writer, and the stage of ripeness in every instance was noted, thus largely eliminating uncertainty as to this point. The analytical determinations for the most part were duplicated with concordant results. At this point thanks are extended to the growers in the several districts for their cooperation in this work.

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[1] Florida Sta. Bul. 101.

[2] U. S. Dept. Agr., Bur. Chem, Bul. 107 (rev.), p. 77.

The following table shows the composition of pineapples that ripened normally in the field:

The composition of normally ripened pineapples.

Localities.	Serial No.	Nitrogen.	Acidity as H_2SO_4.	Reducing sugars calculated as invert sugar.	Sucrose.	Total sugars.	Polarization.		
							Direct.	Invert.	Temperature.
		Per ct.	Per ct.	Per ct.	Per ct.	Per ct.	°V.	°V.	°C.
Wahiawa	....	0.06	0.66	3.92	6.78	10.70	5	−3.6	31.7
Do	101	....	.56	3.94	7.97	11.91	6.4	−3.7	32
Do	105	.09	.43	5.10	7.54	12.64	5.8	−3.8	30.5
Do	110	.09	1.03	4.72	9.88	14.60	7.4	−5.1	32.3
Do	111	.07	.86	5.18	10.05	15.23	8	−4.7	32.7
Do	112	.07	.99	4.59	10.12	14.71	8.4	−4.4	32.3
Do	113	....	1.06	3.50	8.47	11.97	6.6	−4.2	30.3
Do	114	.09	.71	4.12	6.93	11.05	4.9	−3.9	31.4
Do	115	.07	.82	3.14	7.15	10.29	5.3	−3.8	31
Do	102	....	.53	3.84	8.36	12.20	6.9	−3.7	31.5
Ahuimanu	106	.08	1.05	3.86	9.45	13.31	7.7	−4.3	31.4
Do	107	.09	1.16	4.18	8.40	12.58	7.1	−3.6	30.8
Do	108	.08	.63	2.78	7.36	10.14	5.4	−4	30
Do	109	.09	.75	3.56	8.12	11.68	6.3	−4	31.7
Haiku	140	....	.45	4.35	6.08	10.43	4.2	−3.5	32
Do	141	....	.68	4	6.97	10.97	4.9	−4	30
Do	142	....	.63	4.87	6.47	11.34	3.9	−4.3	30.2
Do	143	....	.65	4.85	6.85	11.70	4.6	−4.2	28.6
Do	144	....	.61	5.55	6.03	11.58	4	−3.7	30
Average	....	.08	.75	4.22	7.84	12.06	....	....	....

The above data show that Hawaiian pineapples vary considerably in composition. In general the acidity increases with the sugar content, and the average of the total sugars is about equal to that of pineapples from Florida and the West Indies.

In the following table is shown the composition of green pineapples, gathered just before the beginning of the ripening process:

The composition of pineapples just before the beginning of the ripening process.

Localities.	Serial No.	Acidity as H_2SO_4.	Fiber.	Solids in juice.	Hydrolyzable carbohydrates.	Reducing sugars calculated as invert sugar.	Sucrose.	Total sugars.	Polarization.		
									Direct.	Invert.	Temperature.
		Per ct.	Per ct.	Per ct.	Per ct.	Per ct.	Per ct.	Per ct.	°V.	°V.	°C.
Wahiawa	127	0.48	....	7.32	....	3.57	1.96	5.53	1.0	− 1.5	30.5
Do	128	.44	0.19	5.92	5.00	3.17	.78	3.95	.0	− 1.0	30.4
Do	131	.30	.16	....	5.07	3.36	.87	4.23	.4	− 0.7	33.7
Do	132	.33	.17	....	5.10	5.03	1.88	4.91	1.3	− 1.1	30
Experiment station	145	.39	....	7.44	8.02	3.33	3.14	6.47	2.5	− 1.5	31
Average	....	.39	.17	6.89	5.80	3.29	1.72	5.01	....	....	....

The above data are interesting as showing the low sugar content of pineapples at this stage of development. None of the fruit examined showed any yellow color, but in each instance the characteristic pale-green color around the basal eyes, which always makes its appearance just before the development of a yellow color, had developed. The appearance of this pale-green color, together with a

flattening of the eyes, is the guide by which the fruit is selected for fresh-fruit shipment. The results show that green pineapples do not contain an excess of acidity or fiber, and from the percentages of hydrolyzable carbohydrates it is apparent that if the fruit is gathered at this stage it can never develop a normal sugar content. Numerous tests at all stages of ripeness have failed to reveal the presence of starch or dextrin in pineapples. It is noteworthy that the ratio of reducing sugars to sucrose at this stage is practically the reverse of that found in the normally ripened fruit.

With the view of determining what changes take place in the fruit in ripening after having been gathered green, a number of pineapples were held at the station until fully ripe. The time required for the completion of this process was usually about three weeks. The following table shows the results of this examination:

The composition of pineapples which ripened after being picked green.

Localities.	Serial No.	Acidity as H_2SO_4.	Fiber.	Solids in juice.	Hydrolyzable carbohydrates.	Reducing sugars calculated as invert sugar.	Sucrose.	Total sugars.	Polarization.		
									Direct.	Invert.	Temperature.
		Per ct.	Per ct.	Per ct.	Per ct.	Per ct.	Per ct.	Per ct.	°V.	°V.	°C.
Wahiawa	133	0.53	0.20	....	5.32	1.48	3.92	5.40	2.4	−2.6	30.7
Do	134	.60	.21	6.78	3.57	1.13	2.26	3.39	1.3	−1.6	28.4
Do	135	.55	.21	6.04	4.75	1.19	3.17	4.36	2.0	−2.0	32.8
Do	136	.63	.25	6.54	3.75	1.06	2.26	3.32	1.1	−1.8	29.1
Experiment station	146	.49	....	5.30	....	1.33	2.06	3.39	1.1	−1.5	32.4
Do	147	.39	....	5.13	....	1.27	2.03	3.30	1.0	−1.6	29.2
Do	148	.39	....	4.99	....	1.37	1.10	2.47	0	−1.4	31.4

The most important changes which took place in the ripening of these pineapples were the conversion of reducing sugars into sucrose, the development of flavor, and a breaking down and liquefaction of the tissues. True fiber and acidity were not materially changed.

The composition of pineapples, one-fourth ripe, is shown in the following table:

The composition of pineapples when about one-fourth ripe.

Localities.	Serial No.	Acidity as H_2SO_4.	Solids in juice.	Reducing sugars calculated as invert sugar.	Sucrose.	Total sugars.	Polarization.		
							Direct.	Invert.	Temperature.
		Per ct.	Per ct.	Per ct.	Per ct.	Per ct.	°V.	°V.	°C.
Wahiawa	126	0.62	7.34	3.03	3.79	6.82	2.8	−2.0	32
Do	129	.59	7.56	2.53	3.34	5.87	2.2	−2.1	28.4
Do	130	.59	8.36	2.83	3.83	6.76	2.6	−2.3	29.4
Experiment station	149	.72	9.20	2.77	5.89	8.66	4.5	3.0	30.8
Do	150	.75	10.93	2.56	5.25	7.81	4.0	−2.7	30
Average	....	.65	8.68	2.74	4.42	7.16	....	....	....

These data show that sucrose is developed at a considerable rate during the early ripening process, although the fruit at this time had stored up only about one-half of its normal sugar content.

The next table shows the composition of the fruit when it is approximately half ripe.

The composition of pineapples when half ripe.

Localities.	Serial No.	Acidity as H_2SO_4.	Solids in juice.	Reducing sugars calculated as invert sugar.	Sucrose.	Total sugars.	Polarization.		
							Direct.	Invert.	Temperature.
		Per ct.	*Per ct.*	*Per ct.*	*Per ct.*	*Per ct.*	° *V.*	° *V.*	° *C.*
Wahiawa	116	0.78	11.83	2.74	7.33	10.07	5.7	−3.6	31.8
Do	117	.67	10.36	2.61	6.70	9.31	5.0	−3.5	31.7
Do	124	.63		2.38	6.83	9.21	4.9	−3.8	30.5
Do	125	.54		4.16	6.09	10.25	5.0	−2.7	32.2
Average		.65		2.97	6.73	9.70			

There is a rapid accumulation of sucrose in the ripening of the pineapple. If the fruit is picked at the half-ripe stage and allowed to ripen thoroughly, it will develop a normal flavor and be a highly desirable product.

From the foregoing data it is shown that green pineapples contain a small percentage of sugars, and if gathered at this stage never develop into desirable fruit. As the ripening process proceeds normally, sugars are stored up at a rapid rate, so that by the time the fruit is half ripe it contains a fairly high percentage of both reducing sugars and sucrose; and if gathered and allowed to ripen will mature into a highly edible fruit. The acidity of green pineapples is practically the same as that of the ripe fruit, whereas the ratio of reducing sugars to sucrose is reversed.

As pointed out above, the changes in pineapples that ripen after having been gathered are those of rearrangement, rather than the production of sugars. The composition of the fruit shows that it contains no substance of any consequence that could be converted into sugars, and therefore the total sugar content of pineapples does not increase after being gathered. It is a recognized fact in plant physiology that sugars may result from two different processes—first, from the direct action of chlorophyll in the chlorophyll-bearing cells, and secondly, from a breaking down of other carbohydrates. In some instances there is an accumulation of starch in plant organs which later is hydrolyzed into sugars. In the pineapple, since starch was never found in the fruit, it is safe to conclude that the sugar stored up in normally ripening pineapples is manufactured in the chlorophyll-bearing cells of the leaves and then transferred to the fruit;

hence when the fruit is severed from the stalk all communication with the source of sugar is broken, and therefore its accumulation is permanently stopped.

The cells of green pineapples, as seen under a high-power microscope, contain a thickened layer on the interior of the cell walls, and it is with difficulty that the juice is expressed from the cells. As the ripening process proceeds this thickened layer is gradually dissolved until at maturity the cell walls are extremely thin and easily ruptured. If pineapples are gathered green and allowed to ripen, it has been found that there is a dissolving of this thickened coat on the cell walls, thus apparently increasing the percentage of juice in the fruit without materially changing the concentration of the juice. Later a microchemical study of these changes will be made.

Thanks are extended to Dr. Wilcox for advice and many suggestions in this work; also to Miss Alice R. Thompson for valuable analytical assistance.

REPORT OF THE AGRONOMIST.

By F. G. Krauss.

Problems affecting the culture of rice and cotton continue to be the main lines of inquiry of this division, as for several years past.

RICE INVESTIGATIONS.

IMPORTS AND EXPORTS.

The increasing importations of rice from Japan, which amounted to 27,886,102 pounds, valued at $717,064 in 1909, as against 9,656,796 pounds, valued at $221,116 in 1905, has resulted in a gradual and finally a marked decrease in the production of this important crop in Hawaii.

The following table gives the United States customs statistics covering the imports and exports of rice to and from Hawaii during the period referred to above:

Imports of rice into Hawaii.

Year.	Japan.		China.		United States.	
	Amount.	Value.	Amount.	Value.	Amount.	Value.
	Pounds.	*Dollars.*	*Pounds.*	*Dollars.*	*Pounds.*	*Dollars.*
1905	9,656,796	221,116	11,964	245	9,983,491	303,029
1906	12,496,396	283,653	22,600	529	4,129,643	164,683
1907	21,012,842	539,021	13,906	351	755,050	34,144
1908	26,695,642	740,975	6,485	155	95,524	4,821
1909	27,866,102	717,064	13,966	314	109,300	4,358

The exports to the United States from Hawaii during the same period were:

Exports of rice to the United States from Hawaii.

Year.	Amount.	Value.	Year.	Amount.	Value.
	Pounds.	*Dollars.*		*Pounds.*	*Dollars.*
1905	2,771,083	84,414	1908	3,038,624	140,768
1906	5,739,500	223,012	1909	5,823,585	255,210
1907	3,324,107	147,439			

These inroads upon one of Hawaii's staple products are not based upon a competition in prices, but upon quality. The imported product sells at from 25 cents to $1 more per 100 pounds than does the locally grown rice. The Japanese, who are the principal consumers of rice in Hawaii and the sole importers of the Japan products, de-

mand a distinct type of rice whose characteristic culinary qualities are inherent in certain varieties, and also in large part due to the conditions of growth.

RICE IN JAPAN.

With a view of determining, if possible, the varieties and cultural conditions under which the preferred Japan rices are grown, the writer was authorized by the United States Department of Agriculture to undertake such investigations. Accordingly, the fall months of 1909 were devoted to a critical study of the industry in Japan. Valuable data were obtained at several experiment stations, of which the Central Experiment Station at Nishigahara (near Tokyo), the Kinai Branch Station at Kashiwara (near Osaka), and the Kiushiu Branch Station at Kumamoto (in the famous rice region of Kyushu) are worthy of special mention. The last two stations are devoted almost wholly to rice investigations.

At the Kinai Station a fine opportunity was offered to study varieties. Here have been brought all the types of rice grown in the Empire. After six years' study and comparison these have been grouped under 600 more or less constant varieties or strains sufficiently distinct for classification. A hundred of the most distinct types were obtained for experimental purposes, and are now under comparative tests with the best Hawaiian varieties. After inquiry among rice specialists and personal study, the four following standard varieties were determined upon as most promising for Hawaiian conditions, from both culinary and cultural standpoints. The varieties Omachi and Shinriki are the two types now almost exclusively exported to Hawaii, as they find special favor among the large Japanese population, and bring the highest market prices. The varieties Benkei and Miyako are considered of the highest quality in Japan, and are in great demand by those who can afford to buy them. A hundred pounds of choice seed of each of the four varieties were obtained for distribution among Hawaiian growers. Eight prominent growers availed themselves of seed for this spring's planting, and reports of the results of their experiments are now looked for.

The following descriptions of the above varieties are based on a study of pure strains made in the field at the Yamaguchi Demonstration Station, which is situated in the center of the region from which nearly all the Japan rice entering Hawaii is imported, and where these particular varieties are said to attain their highest perfection. A comparison of the behavior of these varieties grown at the station rice trial grounds during the past spring, from the identical stocks described above, should be of value as determining their adaptability to Hawaiian conditions, from the cultural side, at least. Their culinary qualities are, of course, as yet to be determined, and upon this will depend their acceptability to the consumer.

DESCRIPTION OF FOUR NEWLY INTRODUCED JAPAN RICES (PLATE III).

1. Miyako. Average height of plants, 48 inches; inclined to lodge; average number of fruiting culms per clump, 16; panicles large and compact; kernels medium size, awnless; a fair yielder, medium early. Considered the very best variety grown in Japan.

2. Benkei. Average height of plants, 40 inches; stands up well; average number of fruiting culms per clump, 18; panicles compact and heavy; kernels large, awnless; good yielder, early maturing. Considered a promising new variety in Japan, of fine culinary qualities.

3. Omachi. Average height of plants, 48 inches; slightly inclined to lodge; average number of fruiting culms per clump, 15; panicles large but rather loose; kernels medium size, awned; yields well; a type not likely to be appreciated by the Hawaiian grower because of its awned glumes; but strongly recommended by the Japan experiment stations for trial. It is a standard variety of Japan; extensively exported to Hawaii.

4. Shinriki. A standard variety in Japan; largely exported to Hawaii. Of more recent development than Omachi and by some considered an improvement. Average height of plant, 42 inches; stands up well; a heavy tillering sort, averaging 20 to 30 fruiting culms per clump; panicles small to medium; kernels small, awnless; good yielder; classed as a late variety in Japan, but the writer found it maturing at about the same time as the other varieties described above. Considered by the writer a promising variety for Hawaii.

The table below gives the results of the first season's cultural trial of the above varieties in comparison with the old type of Japan rice heretofore grown to a limited extent in Hawaii. The seed was sown February 4, the seedlings transplanted March 15, and the crop harvested June 3, 1910, the growing period being 119 days for all varieties.

Comparative tests of new and old types of Japan rice (spring crop, 1910) grown without fertilization.

Name of variety.	Average height of plants.	Average number of fruiting culms.	Yield of paddy from 100 clumps.	Yield of straw from 100 clumps.	Character of glumes.
New types:	*Inches.*		*Pounds.*	*Pounds.*	
Benkei	28	16.2	4.0	3.28	Awnless.
Miyako	33	16.7	3.75	3.53	Do.
Omachi	31	17.8	4.87	3.61	Awned.
Shinriki	26	23.1	4.23	3.06	Awnless.
Old type:					
Japan rice No. 153	29	19.8	4.15	4.62	Do.

In comparison with the old type Japan rice, No. 153, both Omachi and Shinriki, the two standard sorts in Japan, which are the only varieties imported into Hawaii, outyielded the former. This is in itself a distinct gain should the quality be maintained in future culture. The variety Benkei, which especially appealed to the writer from a cultural standpoint as he saw it growing in Japan, did not quite equal the yield of the old type, but seems promising. Miyako, considered the best type of rice grown in Japan, gave the smallest yield. It is also considered a rather light yielder in Japan, but its

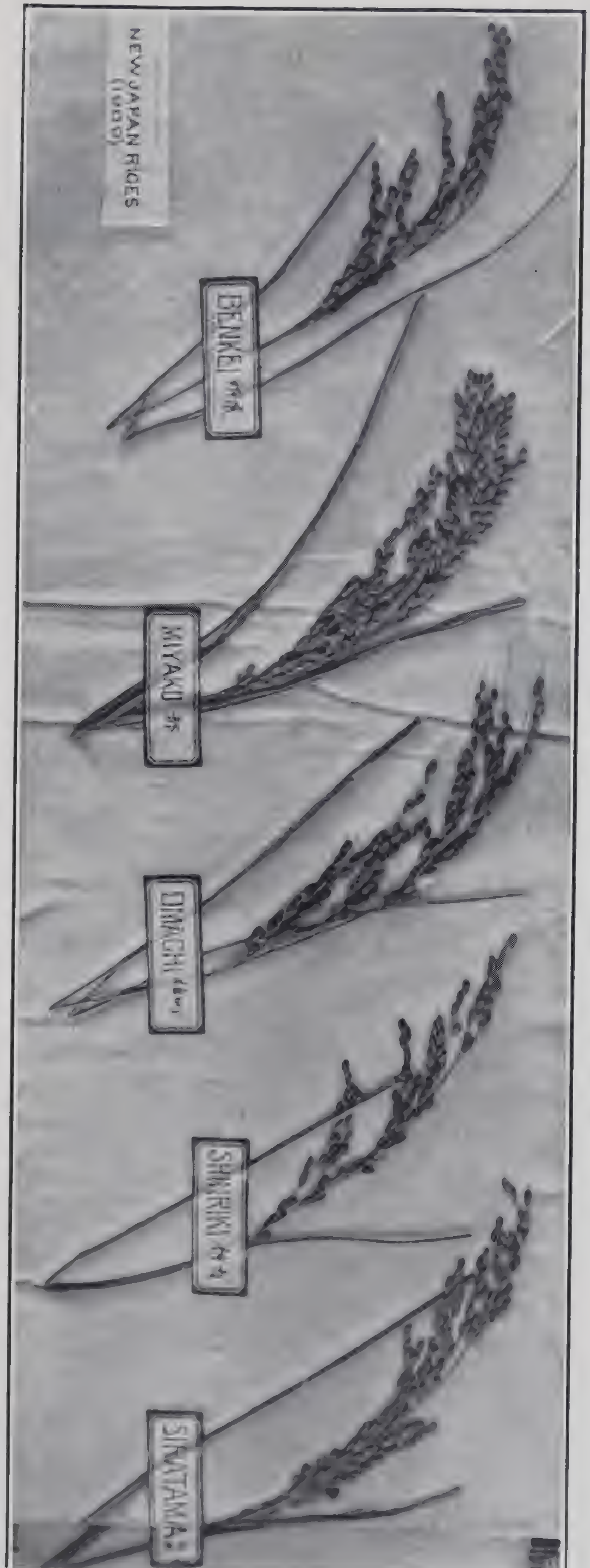
superior quality and consequent high price makes it a leading sort in favored localities. The heavy tillering qualities of Shinriki appear to have been maintained in this trial. From the standpoint of yield. it would appear that Omachi and Shinriki are the most promising sorts. The main objection of the Hawaiian grower to the former variety is its bearded glumes. The Japanese have effected a cross between these two varieties with a view to inducing heavier tillering, beardlessness, and the superior flavor of Omachi in the hybrid. The two former qualities have been effected to a marked degree. Sufficient stock of the hybrid has not yet been grown to make a culinary test. The station was fortunate in securing a small quantity of this hybrid seed for trial.

The figures in Plate III show typical panicles of the several rices just described, and in addition, the variety Saratama. a promising variety, which, owing to its late maturity, can not be described in this report. Panicles of less acceptable types of Japanese rices are shown in Plate IV.

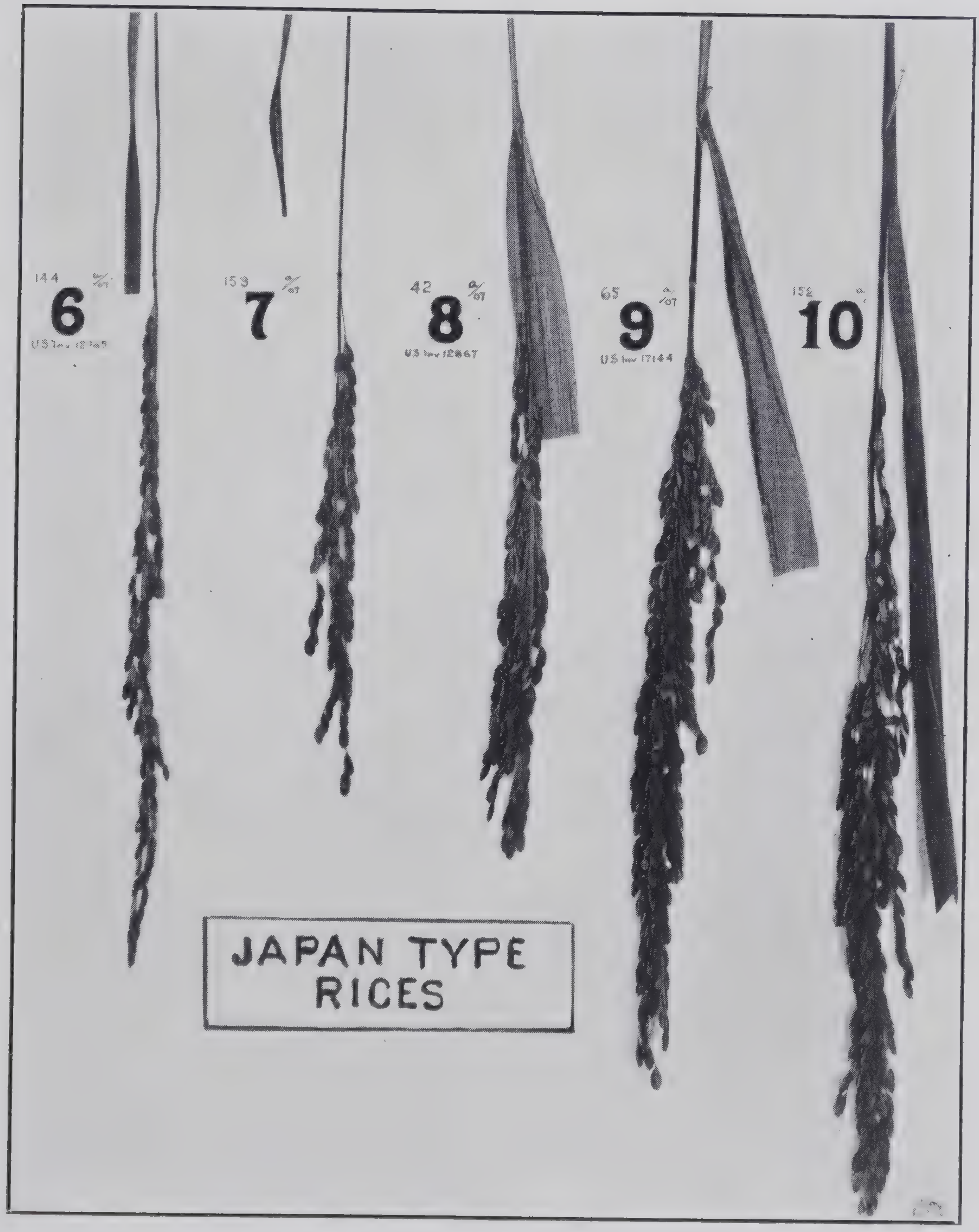
SELECTION AND BREEDING.

In addition to the variety tests of new Japanese and Chinese rices, noted above, the development of pure strains of the best old type is being continued. Some of these strains are now in the seventh generation of selection. A number of these show a marked improvement over the original type, as shown in comparative cultural tests. Increase in yield has been less noticeable than greater purity and uniformity.

Unfortunately, much difficulty has been experienced in inducing growers to perpetuate improved station strains in a pure state. Only limited quantities of station seed are available for distribution, so that growers are dependent upon themselves to produce such seed as they may need for general plantings. However, a season or two of commercial culture almost invariably results in a mixture of varieties. Aside from immediate local benefits, the importance of maintaining pure strains of high-bred rices is well illustrated by a request which came from a rice broker in New Orleans. The station was applied to for samples of choice seed in the hope that a select Hawaiian stock could be obtained to replace the large importations of South American seed used for planting. This is owing to the prevalence of red rice in American seed. A number of local growers submitted samples, but the only stock acceptable was a station strain, for which a substantial advance over current local prices was offered, if obtainable in carload lots. However, too limited an amount was available to make it an object to the purchaser. This experience appears to have renewed the interest in the possibility of growing rice for seed purposes, which has been urged persistently by the



TYPES OF RICE CONSIDERED OF HIGHEST CULINARY QUALITY IN JAPAN.



JAPANESE RICES NOT ACCEPTABLE TO JAPANESE CONSUMER.

station. One grower has asked the station's cooperation in developing this phase of the industry.

Of the several new varieties of rice introduced by the station in past years, variety No. 19 (S. P. I. No. 12508), introduced in 1907, appears to have at last found favor among the more intelligent growers. The Oahu rice mill of Honolulu reports having milled 480 bags, equivalent to 24 tons, during the past season. Other growers and millers are yet to be heard from. Mr. A. Hanneberg, of the Kaneohe Rice Mill Co., who produced several hundred bags of the above lot, speaks enthusiastically concerning this variety and states that it is well suited to the salt-marsh lands, which heretofore were devoted only to inferior rice. Should its adaptability to salt lands and a maintenance of high quality hold true in subsequent practice, a valuable acquisition will have been added to the resources of Hawaii.

Because of the exceptionally heavy tillering, together with the desirable hard, translucent grain of rice No. 19, efforts have for several years past been made to effect a cross between it and the best type of Hawaiian Gold Seed. The latter variety still remains the standard sort with the white and Chinese population, in addition to being one of the leading varieties of export. Could heavier yields and a clearer grain be obtained in Gold Seed, on the one hand, and the fixed property of fall maturity of rice No. 19 be changed to the "all season" cropping habit, which characterizes the Gold Seed, valuable combinations would be effected.

The difficulty thus far has been to get the two varieties to flower at the same time to permit of cross pollination. As the habits are now so well known, it is believed that the extensive plantings planned for this fall will provide the necessary conditions for hybridization.

A careful study was made of the methods practiced by the Japanese in their rice breeding, which has proved very successful during recent years. It is believed that valuable data were obtained as an aid to the contemplated work at this station.

In the study of tens of thousands of individual plants annually by Japanese investigators a natural hybrid among rice was found to be of rare occurrence, notwithstanding the fact that more than 600 varieties have been grown in close proximity for several years past. These results are in agreement with the writer's findings, but contrary to the generally accepted theory.

ROTATION.

The fertilizer investigations with rice having been assigned to the chemical division, this division has had to do with cultural work only. This has included, during the past spring experiments in crop rotation and green manuring, the latter in cooperation with the chemical division. Barley, one of the cereals extensively used in rotation with

rice in Japan, and the established Hawaiian legumes, cowpeas, soy beans, velvet beans, and jack beans (*Canavalia ensiformis*), were planted as rotation crops during the spring, together with the Japanese and Chinese matting plants (*Juncus effusus* and *Cyperus tegetiformis*), which the station has been growing for several years. In addition to the above legumes used as rotation crops, there were planted as green manuring crops *Astragalus sinicus* (the "Genge" or "Renge" of Japan) and *Vicia faba*, the two green-manuring plants most extensively used for rice in Japan. The barleys, of which 50 of the best hulled and naked Japan paddy field varieties were sown, did poorly as a whole, a large percentage failing to head. Some 20 varieties set seed and appear to be fair yielders of grain. All are of very dwarf type, averaging less than 24 inches to tip of spike. Being planted in March, the lateness of season may have had considerable to do with this first poor showing.

Large quantities of barley are imported into Hawaii and its profitable culture in the islands would add materially to their resources. Furthermore, a rotation of a dry-land crop with the submerged culture of rice could not but prove beneficial to the paddy soils, as has been found to be the case in other countries.

The Astragalus used for green manuring proved an entire failure. Planted in March, the seed germinated well, but failed to make more than the feeblest growth. This persisted till the flowering stage and then wasted away, notwithstanding an ample supply of moisture.

The Windsor beans made quite a vigorous growth, but, as in former experimental plantings, failed almost wholly to set seed. It is already quite evident that these two types of green-manuring plants should be planted late in the fall during the coolest season of the year and under moist conditions, such as prevail in paddy fields.

The older-introduced legumes all did well and yielded a large amount of organic matter. Planted in March, the following results were obtained, calculated to acre yields.

Plat III: Soy beans. Variety, Mammoth Yellow; days to turning-under stage, 63; height, 24 inches; yield of green vegetable matter (including main roots), 10,125 pounds; yield as cured fodder (including seeds), 2,500 pounds; yield of seed, 675 pounds; distance of rows, 24 inches.

Plat IV: Velvet beans (*Mucuna utilis*); days to turning-under stage, 75; height of main growth, 28 inches; yield of green vegetable matter (including main roots), 15,300 pounds; yield as cured fodder, 3,420 pounds; yield of seed, 145 pounds; distance of rows, 4 feet.

Plat VII: Cowpeas. Clay type; days to turning-under stage, 75; height of main growth, 36 inches; weight of green vegetable matter (including main roots), 32,400 pounds; yield as cured fodder, 7,200 pounds; yield of seed, 1,417 pounds; distance of rows 4 feet.

Plat VIII: Jack beans (*Canavalia ensiformis*); days to turning-under stage, 75; height of plants, 40 inches; yield of green vegetable matter (including roots), 17,000 pounds; yield as cured fodder, 4,060 pounds; seed not mature at this writing; distance of rows, 4 feet.

Planted March 1, a part of each of the different varieties was turned under about the middle of May, excepting the soy beans, which were turned under 10 days earlier. The jack beans were much the latest to mature, but were turned under with the others to permit of uniform decay before planting the succeeding rice crop.

As will be noted from the above, the cowpeas considerably out-yielded all the other legumes, both in green matter and seed. This is in concordance with a number of previous tests in which many different kinds of legumes were under trial. However, both the velvet bean and jack bean are much surer croppers, being practically immune from the attacks of aphis to which the cowpea is especially subject. The main objections to jack beans and velvet beans are their slow maturity and less palatability. The soy bean, because of its early maturity, lends itself well to short seasons and will often fit in where legumes of larger yield but slower maturity would be out of the question.

The matting plants have not yet been harvested, but their growth compares favorably with that previously reported.

COTTON EXPERIMENTS.

Although still in the experimental stage, the cotton industry in Hawaii has made substantial progress during the past year. Many inquiries have come to the station concerning varieties and methods of culture. Station seed has been widely distributed for experimental purposes, enough being sent out to plant several hundred acres. It is estimated that fully 500 acres are now planted in the Territory. The largest planting comprises about 80 acres. The first commercial crop has been harvested, and is now in bale awaiting shipment. Samples submitted to experts have been pronounced first class; the highest market prices have been quoted.

As announced in the Annual Report for 1909, two extensive cooperative experiments on a field scale were begun in the early part of 1909. The first harvest of these has been completed, and the results, although far from satisfactory from the commercial side, are nevertheless of great value from an experimental point of view.

KUNIA COOPERATIVE COTTON EXPERIMENT.

Kunia lies on the east approach to the Waianae Range, at an elevation of about 600 feet. The soil is a deep, light, silty loam. The region would be classed as semiarid, the rainfall averaging less than 20 inches. The natural growth is guava, lantana, klu, and an occa-

sional large kukui tree, Opuntia and algaroba. The grasses are rather sparse, but manienie, piipii, and other native grasses are met with. The whole growth is characteristic of dry regions. No previous crop had been grown on the lands under experiment.

Preliminary to the experiment the land was plowed in October of the previous year to a depth of at least 24 inches, several times harrowed, and finally plank-dragged, which left the soil in fair condition for planting.

On February 16–19 one-fourth acre was sown to each of the following varieties, Caravonica "wool" (Plate V), Egyptian (Mit Afifi), Sea Island (Georgia and Florida strain), Sea Island ("Seabrook"), and upland "Chinese," as an early planting: and a month later another one-fourth acre was sown as a late planting. All varieties were planted 2½ by 5 feet apart, giving 3,480 plants per acre, except Caravonica, which was planted 5 by 10 feet apart, or at the rate of 870 plants per acre. Each plat consisted of an additional half acre, a third of which was left fallow, a third planted to jack beans as a green manuring or rotation crop, and the remaining third was planted to soy beans and cowpeas. This half of each acre plat was then to be followed with cotton in the succeeding year; thus, in the second year (1910), a comparison between 1 and 2 year old cultures was obtained.

The results of the first year's harvests are given in the following table:

Yields of cotton from first year's harvest, Kunia cooperative experiment.

Plat No.	Variety.	Yield of seed cotton. Weight at picking (¼ acre).	Yield of seed cotton. Weight after 6 months (½ acre).[1]	Yield of lint.	Yield of seed.	Percentage of lint to seed.	Quoted market value of lint.
		Pounds.	*Pounds.*	*Pounds.*	*Pounds.*	*Per cent.*	*Cts. per lb.*
I.	Caravonica "wool":						
	Early planting	32½	54	24	30	44.4	0.29
	Late planting	22					
II.	Egyptian, Mit Afifi:						
	Early planting	95	131	44½	87	33.3	.29
	Late planting	37½					
III.	Sea Island, Georgia-Florida strain:						
	Early planting	107	169	50½	170	29.4	.31
	Late planting	64¼					
[2]IV.	Sea Island, "Seabrook":						
	Early planting	397¾	392	106	236½	30.8	.31
V.	Upland, "Chinese":						
	Early planting	115¾	211	71	140	33.6	.15
	Late planting	119¾					

[1] After the first weights were taken the cotton harvested from the early and late planting of each variety was unintentionally bulked together; hence, the cured weights represent the yield of the two plantings—the product of a half acre. To calculate to acre yields, multiply separate plantings by 4, and the totals of the 2 plantings by 2.

[2] Plat IV, consisting of 1 full acre of early planting, was divided into 13 sections for a fertilizer experiment, the detailed results of which will be reported by the chemist in a later bulletin.

The low yields from this experiment may be attributed to several causes. The rainfall, amounting to about 22 inches for the year, was doubtless inadequate for optimum growth on rough and newly

FIG. 1.—CARAVONICA "WOOL" COTTON 6 MONTHS FROM SEEDING.

FIG. 2.—CARAVONICA "WOOL" COTTON 9 MONTHS FROM SEEDING.

COOPERATIVE COTTON EXPERIMENTS.

FIG. 1.—PRUNING 1-YEAR-OLD CARAVONICA "WOOL" COTTON.

FIG. 2.—SECOND SEASON'S GROWTH OF CARAVONICA "WOOL" COTTON.

COOPERATIVE COTTON EXPERIMENTS.

broken ground. Although the germination was excellent, cutworms attacked the young seedlings from their very appearance above ground, destroying as high as 80 per cent of the stand in some cases. This necessitated repeated partial reseeding. In the case of the early plantings, four reseedings were made, and in the late plantings, two reseedings. These reseedings ranged from 20 per cent upward. It will be noted that the late plantings gave much lower yields than the early plantings, and this gives further proof that the great decrease in yield is due to irregularity of stand. It is safe to say that the original early planting outyielded any subsequent plantings twofold, so that a full stand of the first seeding would unquestionably have given fair yields as judged by mainland standards.

Comparatively little damage was traceable to the bollworm. But during the latter part of the season this pest was much in evidence among the general plantings of the development company, whose cotton fields surrounded the experimental plats. The fertilizer experiments gave good evidence of the value of proper fertilization, as has already been pointed out by the chemist in his report.

The importance of selecting suitable varieties is not fully brought out by the table of yields, but a study of the plants in the field indicates that the Upland type, while slightly outyielding the next best in point of yield, gave insufficient increase to make up for the difference in price.

The Egyptian cotton showed fine individual plants, but the poor stand reduced the acre average below all other varieties, except the Caravonica. This latter variety, as is well known, yields poorly the first year, even under favorable conditions.

The best sections in the fertilized Sea Island plat, as well as the best plants in Plat III, containing another strain of Sea Island, give promise for this variety in seasons of average rainfall. This variety should receive further consideration, because of the high quality maintained by the fiber under adverse conditions of growth.

Judged from the standpoint of general growth, and the subsequent heavy squaring of the Caravonica cotton, this variety unquestionably gives the greatest promise as a drought resister, and would seem the variety especially adapted to this locality. Plates V and VI give a series of views of the Caravonica plat. Figure 1, Plate V, illustrates the growth attained at six months from seed. Figure 2 shows the beginning of the harvest, nine months after planting. While the plants as a whole yielded an average of less than 3 ounces per plant, owing to poor stand and irregularity of the remaining plants, a number of selected specimens yielded over 1 pound per plant. Figure 1, Plate VI, shows the partially dormant plants twelve months after planting, as they were being pruned. Figure 2 of the same plate shows the same plants at the present writing, about

eighteen months from time of planting. The plants are heavily loaded with squares, blossoms, and young bolls, from 100 to 500 fruits in the different stages having been counted per plant. Although less than 6 inches of rain has fallen in the past half year, the plants are growing vigorously, and with every prospect of giving a good yield. It is interesting to note that the irregularity in the size of the plants, presented in the first year, has largely been overcome during the fore part of the second season. All vacant places have been filled in by transplanting one-year old stocks which, with few exceptions, are growing well.

On the basis of the results of the past season the company controlling these lands have added 50 acres of Caravonica to the previous plantings, making a total of about 75 acres.

WAIPAHU COOPERATIVE COTTON EXPERIMENTS.

The Waipahu cooperative cotton experiment is located on the uplands bordering the edge of the upper irrigated cane lands of the Oahu sugar plantation, which faces the Koolau Range. This experiment is a duplication of the Kunia experiment, excepting that the entire acre of each experimental plat was sown in two plantings, instead of half that amount, as at Kunia. The elevation is approximately the same, but the rainfall is somewhat greater, estimated to be about 35 inches per annum. However, the land is more exposed to strong cold winds. A tract of virgin grass land, typical of the region, was selected for the experiment. This was plowed to a depth of about 16 inches in October. The old grass stools littered the field badly and it required considerable tillage to get the field in planting condition. All plantings were completed within a week after those at Kunia.

The results of the first year's harvest are given in the following table:

Yields of cotton from first year's harvest, Waipahu cooperative experiment.

Plat No.	Variety.	Yield of seed cotton ($\frac{1}{2}$ acre).	Yield of lint.	Yield of seed.	Percentage of lint to seed.	Lint calculated to acre yields.
		Pounds.	*Pounds.*	*Pounds.*	*Per cent.*	*Pounds.*
I.	Sea Island, Georgia-Florida strain:					
	Early planting	$62\frac{1}{2}$	$19\frac{1}{2}$	$43\frac{1}{4}$	31.2	39
	Late planting	$42\frac{3}{4}$	$13\frac{1}{4}$	$29\frac{1}{2}$	30.9	$26\frac{1}{2}$
II.	Sea Island, "Seabrook":					
	Early planting	$277\frac{3}{4}$	$87\frac{1}{2}$	$190\frac{1}{4}$	31	$87\frac{1}{2}$
III.	Caravonica "Wool":					
	Early planting	$5\frac{1}{4}$	2.07	3.18	39.4	4.14
	Late planting	[1] 170	[1] 68	[1] 1.02	40	[1] 136
IV.	Egyptian, Mit Afifi:					
	Early planting	$146\frac{1}{4}$	$50\frac{3}{4}$	$95\frac{1}{2}$	34.7	$101\frac{1}{2}$
	Late planting	$23\frac{1}{2}$	8	$15\frac{1}{2}$	34.2	16
V.	Upland, "Chinese":					
	Early planting	113	$39\frac{1}{4}$	$73\frac{3}{4}$	34.7	$78\frac{1}{2}$
	Late planting	$35\frac{1}{4}$	$12\frac{3}{4}$	$22\frac{1}{2}$	36.4	$25\frac{1}{2}$

[1] Weight in grams.

A comparison of the Kunia yields with those obtained at Waipahu shows a considerably lower yield for the latter. This can, to only a small degree, be attributed to lack of moisture, because although the soil became quite dry as the season advanced, certain sections in the fertilizer plat gave yields five times as great as the untreated sections under the same condition of moisture. From this it would appear that in these newly opened lands there exists a decided lack of available plant food. The striking differences between the early and late plantings, which were even greater at Waipahu than at Kunia, are largely to be ascribed to a lack of moisture, since at this season no rains occur. From these experiments and the results obtained during the present season, it would seem that early planting is essential on lands in these localities.

The same drawbacks from cutworms experienced at Kunia were repeated here and necessitated the same number of reseedings. It will thus be seen that this pest in itself is an important problem with the cotton grower. The low yields are, of course, in large part to be ascribed to the poor stands and irregular ages of the plants. This is well illustrated by the fact that the yield of 101½ pounds of lint per acre in the case of the early planted Egyptian cotton, represented about 77 per cent of a full stand, without considering the fact that about 60 per cent of the plants represented a second, third, and fourth replanting. It may be further noted that a large number of individual plants from the first sowing averaged 250 bolls per plant, equivalent to at least 2 pounds seed cotton, which would yield approximately 11 ounces of lint. From the above, and from results obtained at the station trial grounds, it would appear that the Egyption cottons have many qualities to recommend them for trial under Hawaiian conditions.

The Caravonica cotton made a much less satisfactory growth at Waipahu than at Kunia, and the yield was nil for all practical purposes. They again started off slowly during the present spring, but as the warm weather came on, appeared to respond quite markedly. However but few bolls have set, and a number of these are falling prematurely, as is also the case on the acre planting made on a neighboring plantation. The cause for this phenomenon has not as yet been determined.

YIELDS.

No data are at hand to show the exact yields obtained from commercial plantings. Reports of yields up to 1,800 pounds of seed cotton per acre for Sea Island and Egyptian cottons have been received from reliable sources, but the areas under consideration have usually been less than an acre. No official report has as yet been made covering the yields of Caravonica cotton from the 25-acre

planting at Makaweli, Kauai, but it is understood to have been satisfactory for a first season's crop. The cotton from the private planting of 20 acres at Kunia has not been weighed at this writing, but will probably yield at a somewhat lower rate than on the experimental plat.

Mr. E. C. Smith reports that his 40 plants of Caravonica cotton at the Peninsula, planted in January, 1908, have yielded during the 12 months preceding December 31, 1909, 280 pounds of seed cotton. This would be equivalent to a yield of 4,760 pounds per acre.

Owing to the serious infestation with the bollworm of the cottons grown experimentally at the station grounds, the cultural data of which formed the basis of Press Bulletin No. 24, the second year's yield of merchantable lint was very low.

The yields of all the varieties entering the second year promised an advance over the first year. The Florida and Georgia strains of Sea Island matured their first bolls May 10–25, as against August 8 of the previous year; but the bolls, while of good size and yielding an excellent quality of lint, proved to be infested with the bollworm in very large proportions. This increased as the season advanced and prevented the completion of records of yield for comparison with the first year's crops.

The Caravonica cottons, with the exception of test No. 104, fared similarly. Test No. 104, however, which was located in another field, gave good results both in yield and freedom from pests. The 26 plants in this test were planted in July, 1907. The average yield per plant was 15.2 ounces of seed cotton, as against 6.3 ounces the year previous. The three best selections gave the following yields: Selection 5, 2.43 pounds seed cotton; selection 6, 2.5 pounds seed cotton; selection 9, 3.43 pounds seed cotton.

The main lesson to be learned from this experiment is the seriousness of the pest factor, as has already been pointed out by the station entomologist.

COTTON BREEDING.

During the past year a good foundation has been laid for the cotton breeding work planned a year ago, as announced in Press Bulletin No. 24. During the year an acre planting of the most carefully selected Caravonica seed obtainable and a smaller patch of equally good Sea Island were planted for seed production.

Some 30 standard varieties, represented by the American Upland, Sea Island, Egyptian, and Caravonica types, together with the two wild native cottons, and a Cuban red and a Peruvian tree cotton, were planted in a comparative test. All have done well, and all excepting the last four have completed their first crop. Careful study and copious notes have been made of each variety, and a large num-

FIG. 1.—THREE-YEAR-OLD CARAVONICA COTTON TREE BUDDED TO SUPERIOR STRAIN, 3 MONTHS' GROWTH AFTER BUDDING.

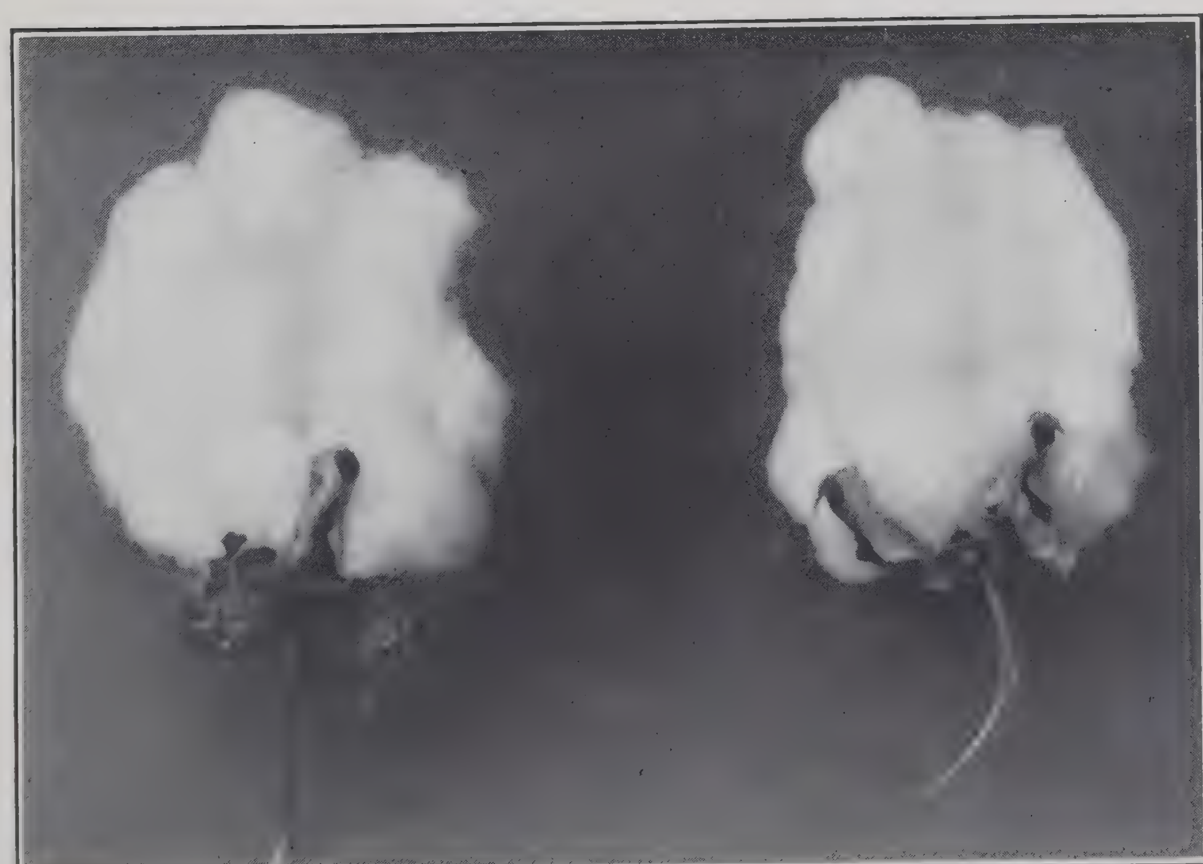


FIG. 2.—IDEAL TYPES OF CARAVONICA "WOOL" COTTON BOLLS.
(Two-thirds natural size.)

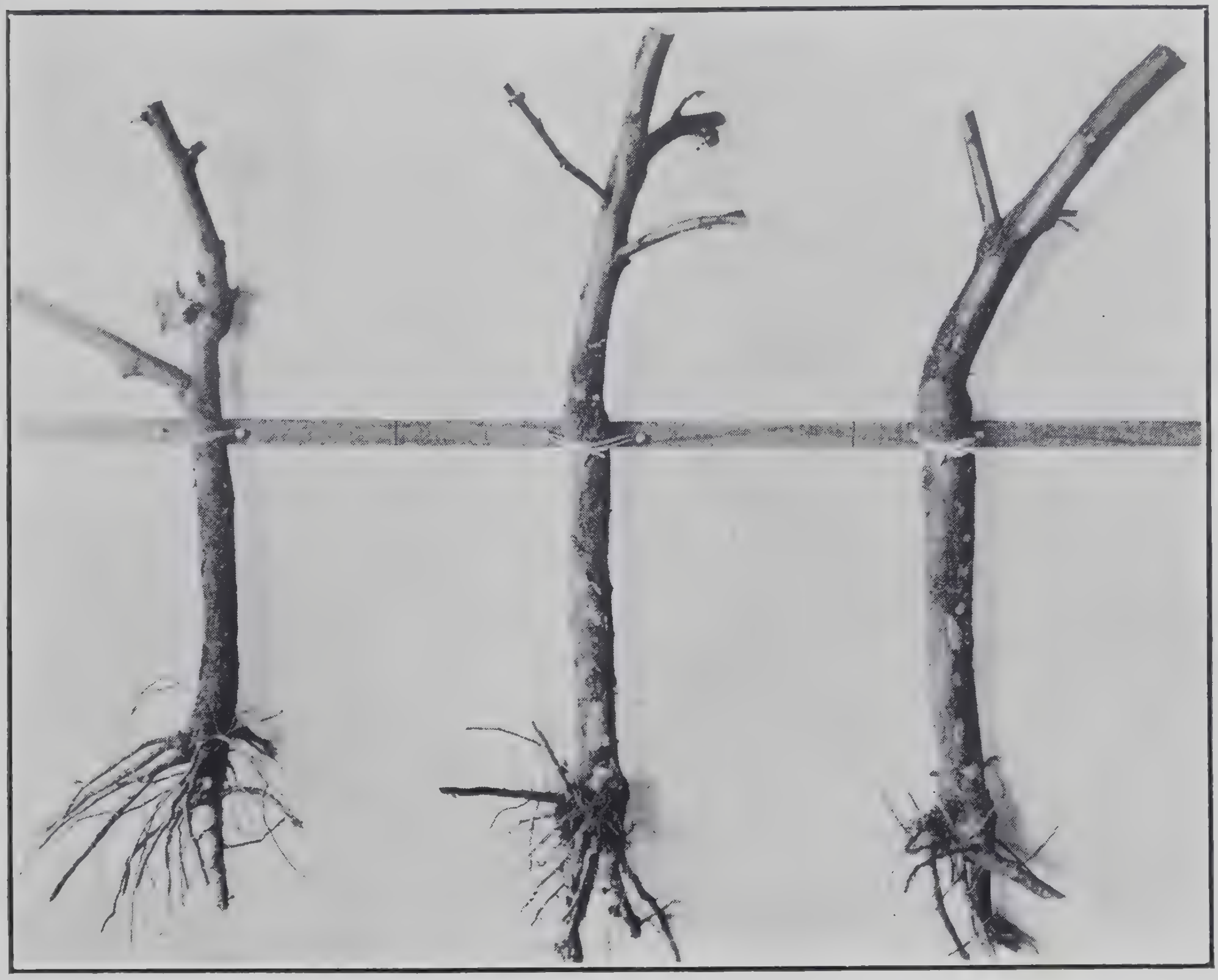


FIG. 1.—ONE-YEAR-OLD CUTTINGS OF CARAVONICA COTTON.

FIG. 2.—PLANTS GROWN FROM ABOVE CUTTINGS, 6 MONTHS AFTER TRANSPLANTING.

ber of superior individuals selected as breeding plants. All the inferior plants not destroyed outright have been budded over to the selections. Twelve hundred buds were inserted. Of these, 380, representing 31 per cent, have made satisfactory growth. A large number of cuttings were also made. Of these from 10 to 60 per cent took root. While these percentages are low, the material available was not always good. A number of minor trials under more favorable conditions were very successful, exceeding 80 per cent.

Plate VII, figure 1, shows a 3-year-old Caravonica tree budded over to one of the superior selections shown in figure 2 of the same plate. Eight of the ten buds inserted are making a vigorous growth. Plate VIII, figure 1, illustrates average specimens of the 1-year-old Caravonica cotton cuttings, described in the Annual Report for 1909. In this original experiment, 90 per cent of the Caravonica cuttings rooted. Figure 2 shows the same cuttings six months after transplanting to permanent location. They are making a very vigorous growth and are blooming profusely, a number of the plants averaging a hundred young bolls at this writing.

For the propagation of selections by budding it is now planned to grow seedlings of a vigorous sort in the nursery, as with the common fruits, and when these are from two to three months old to bud low to a single stem. This has already been demonstrated as feasible by Mr. E. C. Smith, a pioneer worker with this method. In Mr. Smith's experiments practically every bud inserted has grown. The day seems near at hand when one may purchase budded seedlings of a pure strain of superior Caravonica cotton by the hundred or thousand. These would be planted out in orchard rows like so many fruit trees, and a full year of cultivation saved, with a possible saving in cost.

MISCELLANEOUS CROPS.

In addition to the comparative tests of rices and cottons, the usual plantings of new crops, to test their adaptability to Hawaiian needs and conditions, have been under trial during the past year. The number of varieties under test during the past spring has exceeded 200. A large proportion of these was personally selected in China and Japan. Among the above a number of sorghums from Africa, and legumes from Japan, give special promise. These will be reported upon in a forthcoming bulletin.

During the year numerous calls were made upon this division for advice pertaining to problems affecting field crops other than rice and cotton. Among these may be mentioned an extensive cropping system involving a 50-acre cooperative experiment, which was planned for the Molokai Ranch Co. This experiment is now well under way, and is showing substantial results.

TARO.

The gradual decline of the taro crop on a 9-acre plantation near Honolulu has been given some attention during the year. An investigation of the fields during the height of the harvest season a year ago showed a deplorable state of affairs. Different patches showed from 20 to 60 per cent of the corms, the edible underground portion of the plant, to be decayed. The decayed portions were returned to the patches "as fertilizer," and in replanting the "hules" from diseased plants were freely used. No fallowing or rotation had been practiced for 20 years. Such a practice could not be expected to bring about other results. The general treatment outlined in Bulletin No. 2 of the station, entitled The Root Rot of Taro, by the former agriculturist, was recommended. The results thus far are very encouraging. Not more than 5 per cent of diseased plants are apparent at this time, a year after the treatment began.

The agronomist wishes to make acknowledgment of the financial aid and encouragement rendered by a number of the prominent rice growers of the Territory in furthering the rice investigations in China and Japan. Likewise thanks are due to the Japanese and Chinese officials who freely gave information and seeds during the oriental trip. To the members of the station staff who have made valuable suggestions and rendered material aid in various phases of the work in hand, and especially to my former associates, Messrs. Q. Q. Bradford and V. S. Holt, I wish to express my appreciation for their work on cotton. The former did practically all the budding.

A full report of the writer's observations on rice and cotton investigations in China and Japan appeared in The Hawaiian Forester and Agriculturist, beginning with the May, 1910, issue.

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Issued February 20, 1915.

HAWAII AGRICULTURAL EXPERIMENT STATION,
E. V. WILCOX, Special Agent in Charge.

REPORT OF THE HAWAII AGRICULTURAL EXPERIMENT STATION.

1914.

UNDER THE SUPERVISION OF
OFFICE OF EXPERIMENT STATIONS,
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WASHINGTON:
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HAWAII AGRICULTURAL EXPERIMENT STATION, HONOLULU.

[Under the supervision of A. C. TRUE, Director of the Office of Experiment Stations, United States Department of Agriculture.]

WALTER H. EVANS, *Chief of Division of Insular Stations, Office of Experiment Stations.*

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J. DE C. JERVES, *Superintendent Homestead Substation.*
J. K. CLARK, *Superintendent Waipio Substation.*

LETTER OF TRANSMITTAL.

HAWAII AGRICULTURAL EXPERIMENT STATION,
Honolulu, Hawaii, July 30, 1914.

SIR: I have the honor to transmit herewith and to recommend for publication a report of the Hawaii Agricultural Experiment Station, 1914.

Respectfully,

E. V. WILCOX,
Special Agent in Charge.

DR. A. C. TRUE,
Director Office of Experiment Stations,
U. S. Department of Agriculture, Washington, D. C.

Publication recommended.
A. C. TRUE, *Director.*

Publication authorized.
D. F. HOUSTON,
Secretary of Agriculture.

CONTENTS.

ILLUSTRATIONS.

REPORT OF THE HAWAII AGRICULTURAL EXPERIMENT STATION, 1914.

SUMMARY OF INVESTIGATIONS.

By E. V. Wilcox, *Special Agent in Charge.*

BUILDINGS AND GROUNDS.

The glass propagation house which was erected for use in propagating delicate cuttings and seeds was originally fitted with a water tank on one side which was covered with glass. This was intended as a sun heater, the water circulating through pipes under the propagation beds and connected with the tank on the outside. It proved unsatisfactory, however, and a rearrangement was made by which a gasoline heater was sunk into the ground alongside of the propagating house. This arrangement has given satisfactory results.

The sedge commonly known as Japanese nut grass (*Cyperus rotundus*) has become generally distributed throughout Hawaii and has proved to be a most difficult weed to eradicate. Several patches of it have become established on the station grounds, in fact it is practically impossible to prevent its accidental introduction through seeds carried by animals or on the shoes of visitors. The remarkable quickness with which the nut grass springs up after hoeing makes it an unusually serious pest in all cultivated fields except in the case of tall crops like cane or pigeon peas which ultimately shade the nut grass out. The apparent destruction of the nut grass by this means, however, is a delusion, for as soon as the crop is harvested the nut grass begins again unabated. The only method by which this pest has been successfully controlled thus far is that of mowing at intervals sufficiently frequent to prevent the weed from forming seeds. If this practice be persisted in for a sufficient length of time, the underground bulbs become exhausted and the plants die. This method, however, is not applicable in cultivated fields. A series of experiments has therefore been devised to test various methods of eradication, such as hoeing, harrowing, cutting, and spraying with arsenite of soda at intervals so timed as to prevent the weed from seeding. It is hoped in this way to find a practical method by which the further spread of nut grass can be prevented.

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About 7 acres of land adjoining the station grounds and belonging to the Public Health and Marine Hospital Service were turned over to the station for agricultural use for an indefinite period. Not all of this area has soil adapted to agricultural purposes. The whole tract has been fenced and about 5 acres of land cleared ready for plowing. It may not be possible to put water for irrigation purposes on this land, but the rainfall during the autumn and winter is sufficient for the growth of winter crops of garden vegetables, cereals, and other crops which it is hoped to test out during the coming year.

One of the chief needs of the station at the present time is a tract of uniform soil which can be devoted to permanent plats for experiments with fertilizers and a rational system of rotation. The need of such a set of plats has become more and more urgent. The present location of the station was poorly chosen in so far as prospects for scientific fertilizer tests are concerned. The soil is conspicuously lacking in uniformity. The physical and chemical nature of the soil changes every few rods and the patchiness of the soil on the station grounds as a whole is one of its most obvious features. Outside of pot experiments, the fertilizer experiments of the station have been made on the substations and by cooperative arrangements with pineapple growers who happen to possess large tracts of uniform soil. No matter how smoothly, however, a cooperative experiment may be operated, it suffers from the great disadvantage that it can not be permanent nor extend over a sufficiently long period. A tract of land which would be well adapted to the purposes of permanent fertilizer experiments lies near the town of Wahiawa and within the army reservation of Schofield Barracks. This tract is separated by a gulch from the remainder of the reservation and could, therefore, not be used by the Army for maneuvering. It is hoped that an arrangement may be effected by which the station can secure the use of this land permanently for agricultural purposes. A series of experiments could then be organized and carried on in a systematic manner so that the effects of certain fertilizer applications and certain systems of rotation would be permanently on exhibit as an evidence of the scientific value of the fertilizer experiments undertaken, and of the practical value of the system thus adopted for the use of the surrounding pineapple growers and other farmers. The experiments now in progress on a small tract of land on Wyllie Street, leased by the station, indicate that the results thus far obtained in comparing aeration and nonaeration of the soil between crops of rice are rendered somewhat doubtful by the lack of uniformity of the soil. This tract therefore can not be used for the purpose in question, but must be devoted to other work where uniformity of the soil is not of so much importance.

The growth of the station has brought about the urgent need of another building of about the size and proportions of the present office building. The present office building is needed exclusively for office, library, mailing room, and storage of bulletins. The quarters of the entomologist are at present in the office building. The building in which the departments of agronomy and chemistry are now housed is all needed for the chemical department. The horticultural department occupies a small building not well adapted to the work of the department. A new building of the size of the present office building would furnish room for the departments of agronomy, horticulture, and entomology for a number of years to come.

CHANGES IN THE STAFF.

D. T. Fullaway, at the request of the Bureau of Agriculture of the Philippines, was furloughed for work in connection with that institution from October 15, 1913, to February 28, 1914. He was again furloughed on June 1, 1914, for a period of one year to search for parasites of the Mediterranean fruit fly, under the auspices of the Territorial Board of Agriculture and Forestry. J. E. Higgins was absent on furlough during the whole year for work in connection with the University of Porto Rico. C. K. McClelland resigned to accept a position as agronomist at the Georgia Experiment Station. It is proposed for the present at least to have the assistant agronomist continue the work of that department under the direction of the chemical department in order to affiliate more closely the work along those two lines. A plant pathologist is greatly needed at the station. The funds which have thus far been available were not sufficient to make possible the employment of a man for this purpose. There are a number of plant diseases in Hawaii which need investigation. Prominent among such diseases are a banana disease of unknown nature, anthracnose of mango and avocado, and a blight of potatoes.

SUBSTATIONS.

The problem of greatest importance at the Glenwood substation is that of producing suitable forage and other feeding stuffs for dairy cows. The large tract of land devoted to dairying in the neighborhood of the substation presents some peculiar difficulties which must be overcome. The general peculiarity of the neighborhood is the excessive rainfall, which ranges from 200 to 350 inches per year. Occasionally there are years in which there are not more than 20 days in which heavy rainfall does not occur. Many of the legumes apparently can not be made to thrive under these conditions. The same may be said of certain grasses and other forage plants. It is of course impossible to produce hay under such conditions without

an apparatus for artificial drying. The only possible means of storing feed is a silo. A silo has been erected at the substation and a number of experiments have already been made with the different crops for silage. The making of cane silage has offered no more difficulties than are to be met with corn silage, and cane silage of excellent flavor and well liked by cows has been made. The whole sugar cane, including stem and leaves, may be ensiled, or merely the cane tops. No unfavorable fermentation has been found to take place if the silage is properly packed. The acid in sugar-cane silage at the end of three months was found to be only 0.2 per cent. Excellent results were also had with sorghum and Para grass as silage plants. As a soiling crop, honohono (*Commelina nudiflora*) has come into great prominence. This plant grows wild throughout the Glenwood section and ratoons readily, giving heavy crops in succession, particularly if a top-dressing of manure is added from time to time after cutting.

The pure-bred Guernseys purchased for the substation have given a good account of themselves. The registered bull has been much used for service among the cows of neighboring dairymen with the result that there are now 15 grade heifer Guernseys sired by the substation bull.

The creamery work of the Glenwood substation has been reorganized on a slightly different plan from that which prevailed last year. It was found unsatisfactory to ship milk from Hilo and other distant sections to the substation creamery. The cream showed too high a percentage of acid. While the number of cows in the neighborhood is gradually increasing, there are not enough at present to make practicable a cooperative creamery run by the dairymen themselves. The essential features of the association already formed have been retained in the present organization under the title of the Hawaii Butter Makers' Association. Such members of the association as live at too great a distance from the creamery now make their own butter. The milk from the dairies in the immediate vicinity of the substation creamery is separated and butter made for the actual cost of the operation. All of the butter made at the substation creamery and by all other members of the association living at a distance from the creamery is sold by the secretary of the Butter Makers' Association. This butter has made a satisfactory place for itself on the market in Hilo and in Honolulu.

The Glenwood substation is also carrying on experiments with poultry and ducks. A flock of Rhode Island Red chickens is maintained at the station as a general purpose breed, and White Leghorns are raised for egg production. The system of deep litter brooders is used with pronounced success.

At the Hilo substation experiments with bananas and taro have been continued. A study of the varieties of taro of most economic importance has been made and descriptions are being prepared. This material, together with results of experiments in various methods of propagating taro, various distances of planting, and the use of various fertilizers will be ready for publication as a taro bulletin during the coming year.

The work at the Waipio substation is of a cooperative nature. The main problem for the year was a study of onion production. Red and white Bermuda onion seed was planted directly in drills in the fields on September 23, October 3, October 9, November 13, and December 10. Part of the seed was planted in shallow furrows and part in level culture. The Waipio substation is in a region of low rainfall, but unusually heavy rains occurred this year, filling the furrows with soil and burying the onion bulbs. Considerable thinning and transplanting had to be done throughout this area, and the bulbs buried by washed soil had to be uncovered. The best results were obtained from the sowings in September and October. November and December appear to be too late. Areas on which trash was burned not only produced larger onions, but the onions required only 90 to 100 days from seeding to maturity, as compared with 130 to 160 days on areas not burned. It is planned to carry on some experiments to determine whether it may be economical to heat the soil in the rows by means of a crude-oil blast before planting. The area planted to onions was 8 acres. Most of the soil showed 3 per cent manganese by analysis. From seeding to harvest 23 inches of rain fell. The 8 acres of onions yielded 32,210 pounds, not counting the small onions of pickling size.

At the Nahiku substation the most important result obtained during the year was the demonstration that by means of cuttings from heavy yielding trees, a whole plantation of rubber can easily be obtained with a yield approximately that of the most prolific trees. In the experiments carried out in Nahiku, whole trees of *Manihot glaziovii* of known high yield were sawed into cuttings three or four feet long and planted in the wet soil. The cuttings take root and begin growth very promptly, whatever may be the size of the cuttings. Some of them were 5 inches in diameter.

The roselle experiment was continued during the year with the result that higher yields were obtained than had ever been reported for roselle, approximately 17,000 pounds of fresh fruit per acre. A drying plant has been erected for preparing the material promptly for shipment. Two hundred acres of roselle are now growing, and from the present condition of the plants it is to be expected that a large yield will be obtained at the next picking.

A 10-acre fertilizer experiment on Ceara rubber was carried out during the year. The results of this experiment while interesting are not sufficiently pronounced to warrant the conclusion that fertilizers would pay when applied to rubber in the Nahiku district. The best results both in yield of latex and in growth of trees were obtained from the use of superphosphate and potassium sulphate, without the addition of nitrogen in any form. The soils in question are rich in humus and nitrogen.

At the Homestead substation particular attention was given to the relative economy and profits to be obtained from the growing of various crops, including sugar cane, pineapples, peanuts, field corn, and sugar corn. The results obtained indicated that pineapples yielded the greatest profit, followed by sugar cane and sweet corn. The relative economy from these crops, however, varies from year to year on account of the irregularity in prices. At present the prices offered by the canneries for pineapples are less than the cost of production.

COOPERATION WITH MILITARY POSTS.

During the year the amount of cooperation with military posts has greatly increased. For the most part new work in grading and street making at the Army and Navy posts has made it necessary to secure large quantities of ornamental plants and fruit trees in order to overcome the barren appearance of the new grounds. Along this line of work the station staff has furnished plans, general advice, and a large amount of material for planting. At Schofield Barracks a rather elaborate farming experiment is in progress in cooperation with the station. About 60 acres of land have been planted in legumes, Sudan grass, sorghum, Japanese cane, and other forage plants for the purpose of furnishing green feed for Army mules and horses. As a result of the favorable outcome of this experiment it is likely that the authorities at Schofield Barracks will extend their farm operations for the coming year. The United States Army is one of the largest factors in Hawaii in bringing about the greater development of diversified farming. The Army already uses algaroba meal as a part of its mule and horse ration and will take corn as another portion of the ration as soon as it is produced in sufficient quantities. The Army contracts call for 28,000 pounds of onions per month and 240,000 pounds of potatoes per month. During the past year onions were supplied from local sources for two months only, but potatoes not at all. The Army purchased outside of contract large quantities of eggs, poultry, and miscellaneous farm produce. The military authorities are desirous of having the Territory develop a completely independent source of food supply.

MARKETING DIVISION.

At the 1913 session of the Territorial legislature an act was passed providing funds for this station to be used in furthering the marketing of miscellaneous agricultural crops. The Territorial marketing division was established under the supervision of the station on July 1, 1913. The produce sent in by farmers has increased during the year from $84 to nearly $6,000 per month. The total value of produce received and handled by the marketing division during the year amounts to $26,500, at a cost of $2,000.

The effect of the establishment of the marketing division is apparent throughout the Territory in the greatly increased interest in diversified farming. Heretofore most of the ordinary farm produce consumed in the Territory has been imported. There were only a few farmers who were raising miscellaneous produce, and the small quantity of produce which they raised was totally insufficient to furnish a uniform and satisfactory supply. Dealers in Honolulu, therefore, depended upon the mainland supply. Moreover, the price obtained by farmers for their produce was not sufficient to encourage general agriculture. So unsatisfactory a state of affairs had arisen that the most practical question was not how can a crop be grown, but can it be marketed. The chaotic state of the Honolulu market and high freight rates made it impossible for the farmer to raise miscellaneous produce at a profit.

As a result of the establishment of the marketing division various lines of farming have been developed with profitable results. The shipment of produce from all parts of the Territory to one central market insures a large enough quantity of each kind of produce to occupy a place in the market, and also insures a fairly uniform and constant supply. These conditions having been met, the interest shown in local produce by Army posts, hotels, boarding houses, schools, and other institutions, as well as wholesale dealers, has been gratifying.

The effect of the market has been perhaps most noticeable in the poultry industry. Nearly all farmers who have been interested in this line of work have increased their equipment and the size of their flocks and are prepared to be in a position to supply the demand for eggs and poultry in the Honolulu market. The marketing division issues weekly quotation sheets of the prices which have prevailed during the week on all local produce. These sheets are sent to all interested farmers and to the newspapers of the Territory. Blank forms are also sent out to interested farmers on which they can give the market information as to the amount of various crops planted, when planted, and approximately the quantity and probable time of delivery of the crop to the market. This enables the marketing

division to arrange for sales of produce in advance and thus facilitate the prompt handling of the crop. A list of breeders of pure-bred stock is kept, by means of which farmers can be placed in communication with such breeders and secure breeding stock when it is desired.

The work of the marketing division for its first year indicates two directions in which further development is needed. A branch office is required in San Francisco to handle shipments of fresh pineapples, bananas, coffee, sweet potatoes, onions, beans, kukui nuts, coconuts, and the surplus of any other produce which may be raised in Hawaii. At present the business of growing pineapples in so far as the small independent growers are concerned is almost hopeless. The cost of producing pineapples ranges from $12 to $15 a ton. The price offered by the canners at present ranges from $5 to $11 per ton for first-grade pineapples and one-half those prices for second grade. The only hope for the small grower, therefore, until these conditions are rectified, is to find a good market for his fresh fruit on the mainland. The business of shipping fresh fruit can not be carried on satisfactorily without organization. It has been tried by the pineapple growers too many times with disastrous results. If all fresh pineapples were shipped under the direction of a central office in San Francisco, as a branch office of the marketing division, it would be easily possible to prevent a regular succession of bare and flooded markets which have characterized the previous condition of pineapple shipments. Similarly with other produce, a branch office of the Territorial marketing division in San Francisco could create and supply a much larger market for local produce than is now in sight.

Another direction in which the work of the marketing division could profitably be extended is in the line of a retail department. If a cooperative store were established in Honolulu, the farmers of the Territory would be glad to furnish their produce to this store through the marketing division in order to secure for themselves a regular sale of their produce at a reasonable profit, and to secure to consumers the possibility of a constant supply of local produce at reasonable prices.

CHEMICAL INVESTIGATIONS.

The effects of heat were studied on twelve different soils of varying types, the soils being heated to 100 and 250° C. and to ignition. On the whole the effect of applying heat to soils was to render plant food compounds and other chemical compounds more soluble. The most important effects of heating soils are apparently included in the processes of flocculation, oxidation, double decomposition, and alteration of soil elements. There was a slight loss of total nitrogen from heating. One of the striking effects was the unusually rapid formation of ammonia after the soil had been heated. Heating soils

seems to bring about rapidly the effects which are otherwise obtained more slowly by aeration. It has been noted in the case of all plants with which experiments have been made that growth is much more rapid on heated than on unheated soils.

Further experiments on the fertilization of rice substantiated the results already obtained along this line. In nearly all of the rice soils of Hawaii ammonium sulphate or some form of organic nitrogen seems to be the fertilizer most needed. Poor growth results from the use of nitrate as a source of nitrogen for rice. Experiments to determine the possible effect of aeration of the soil between rice crops indicated some advantage from aeration, but the experiments were inconclusive on account of the lack of soil uniformity in the experimental plats.

The investigation of the nature of nitrogen compounds in the soil has been continued and the subject studied from various standpoints. The results thus far obtained indicate that bacteria cause more rapid decomposition of the diamino acids than of the other groups present in protein. A further study of this subject is being made on pure proteins. The hydrolytic and other decomposition products of proteins will receive further study.

Attention has been devoted also to a study of the physical properties of soils with interesting results. In heavy clay soils all fertilizers used alone or in mixtures at the ordinary rate have been found to check the movement of soil moisture. Sodium nitrate increased the water-holding power of soils and also increased the rate of percolation of the water. Corresponding with this there was a diminution of the capillary rise of moisture. Capillarity was found to be greatest in silty soils, less in sandy soils, and least in heavy clay soils. In all these experiments the increase in the concentration of the fertilizer salts caused a diminution in the capillary movement of water. In ordinary soils all fertilizers diminished the percolation of water through the soils. Lime and magnesia salts checked percolation less than the salts of sodium, potassium, and ammonium. In clay soils chlorids were found to check the flow of water less than sulphates, while the reverse proved to be true in the case of organic soils. In each case the soil which showed greatest capillarity offered the greatest resistance to the percolation of water. It was demonstrated that fertilizers exert physical effects which are perhaps more easily detected and measured than are chemical effects.

In a study of the function of fertilizers in soils it was found that phosphoric acid was fixed to a greater extent than other fertilizers. This fertilizer proved most effective when applied in the most soluble form. While, however, phosphoric acid in soluble form was fixed in the soil to an almost indefinite extent in so far as leaching is concerned, it still remained readily available to plants, as shown by the

70966°—15——3

decided residual effect of phosphoric acid upon three successive crops grown without additional application of phosphoric acid. Ammonia was fixed to a greater extent than potash, but was less firmly held by the soil, and may become available more promptly. Nitrates were not fixed by Hawaiian soils to any appreciable extent. It was found that there was less loss by fixation in the soils when fertilizers were applied singly than when applied in combination. More deflocculation took place, however, when fertilizers were applied singly.

Continued study of the lime-magnesia ratio in Hawaiian soils brought additional evidence that this ratio is not important in itself. It becomes important only when soluble salts are in great excess or when the soil solution is greatly concentrated and the mineral matters out of normal proportion.

Additional evidence has been accumulated that attention to aeration is especially necessary for the proper growth of plants in Hawaiian soils. No nitrification took place without aeration. In soils which have been left fallow for a year or more there was practically no nitrate nitrogen, but nitrification took place rapidly as soon as the soils were thoroughly tilled.

Volatile antiseptics and heat were found to increase ammonification for a period of two weeks. Nitrification then began after about three weeks, and gradually increased to a maximum. Volatile antiseptics in experiments at the station did not kill protozoa, but these organisms were easily killed by heat. The evidence accumulated in soil work at the station is against the possibility of protozoa being connected with nitrification in soils.

Continued pot experiments with various forms of phosphate have demonstrated anew that soluble phosphates do not leach through the soils, but remain permanently available for plant growth. It was also shown that legumes used as green manure greatly increased the availability of rock phosphate.

Analyses were made of all the common tropical fruits in Hawaii. A special study was made of the changes which take place during the ripening of bananas and papayas. A study was also made of the organic phosphorus of rice. This is of particular importance on account of the extensive use of rice as food. The organic phosphorus compound was found to be formed chiefly in the bran or outer layer of the rice grain.

HORTICULTURAL INVESTIGATIONS.

The attempt to establish a strain of papaya with self-fertile flowers and with male trees eliminated has been continued. The results give promise of complete success within two or three more generations of papaya. The examination of 454 trees of the second generation

of breeding showed that $95\frac{1}{3}$ per cent of these trees are fruit bearing trees with perfect flowers. Two male trees were cut off 3 feet from the ground and when the new branches came out it was found that the sex had been changed and that regular, perfect flowers, each bearing fruit, were developed.

From the orchard records kept at the station interesting data are now available regarding the average age at which budded, inarched and seedling mangoes and avocados have come to bearing.

On account of the prevalence of the Mediterranean fruit fly it was found necessary to bag some of the fruit which was needed for experimental purposes. Ordinary paper bags were used for this purpose and proved to be a cheap and efficient means of protecting the fruit.

The local interest in hibiscus continues unabated. A number of new varieties have been originated at the station since the publication of Bulletin 29. Perhaps the most interesting ones are two yellow-flowered varieties originated by self-pollination from pink varieties and a semidouble white. Many worthy varieties have also been produced by private breeders and the types have been sent to the station for description. The pink cotton bollworm has been found to breed quite freely in the pods of those varieties of hibiscus which form seed.

A nearly spineless cactus, supposed to have been introduced into Hawaii by Don Marin, has been grown at the station for several years. An opportunity offered to test the hardiness of this cactus in comparison with a number of other drought-resisting plants and several varieties of Burbank's cactus. All of these plants were set out on the island of Kahoolawe in an excessively dry region somewhat exposed to wind. At the end of six months the place was visited again when it was found that none of the plants had grown except the Marin cactus which was growing satisfactorily. In the few tests which the station has been able to make, this cactus, under dry conditions, has grown about three times as fast as the Burbank varieties.

AGRONOMICAL INVESTIGATIONS.

A variety of Japanese rice known as Bezembo was obtained from James Armstrong, of Pearl City. This variety yielded about the same as the other varieties of Japanese rice with which the station has experimented, but matured about 10 days earlier. Experiments will be continued under more favorable conditions to determine definitely whether the æration of the soil between rice crops is of benefit or not to the growth of rice.

Year by year tests are carried on with various cereals in order to determine what kinds fit in with the agricultural program of Hawaii and what varieties can be recommended for Hawaiian conditions. At low altitudes wheat seems to offer no promise. Rye, oats, and certain varieties of barley make a more satisfactory growth. There is a tendency in barley, however, to stool excessively without forming seed heads. Considerable difficulty has been experienced in carrying African sorghums to successful seeding. Seed eating birds are so numerous that it is impossible to save the seed on sorghum plats without bagging the heads. The heads, however, do not develop quite normally under bags.

Among the numerous grasses which have been tried at the station, Sudan grass and Giant Bermuda grass have perhaps attracted most attention. Sudan grass grows rapidly and produces a heavy yield wherever it has been tried in Hawaii except at high elevations. The greatest growth of this grass was obtained on Molokai, where it reached a height of $10\frac{1}{2}$ feet in 70 days. It ratoons promptly and satisfactorily wherever it has been tried. Giant Bermuda grows with unusual rapidity and gives promise of being a valuable pasture grass. Teff grass (*Eragrostis abyssinica*) and saltbushes may also be added to the list of promising forage plants.

The prevalence of blight renders potato raising a precarious venture. Experiments have been carried on at the station for two years in an attempt to develop a system of spraying which would control this disease. The results are still unsatisfactory but give promise that the disease may be overcome. Both Bordeaux mixture and lime-sulphur preparations have been used. The life of the vines is somewhat prolonged but not sufficiently to enable the potatoes to mature perfectly. There is need of a careful study of this disease by a trained pathologist.

Buckwheat and flax have given excellent results in growth and appearance of the plants and in yield. Little trouble seems to be experienced in the growth of these plants in Hawaii either from insect pests or diseases or even from soil conditions.

ENTOMOLOGICAL INVESTIGATIONS.

On account of the absence of the entomologist from the station on furlough for a considerable portion of the year the only systematic work in entomology carried on during the year was on tobacco insects and vegetable diseases. Many of these pests had been previously studied in Hawaii or elsewhere, but the life history of each pest was gone over again in detail so far as possible. Recommendations based on practical experience were made concerning the possible means of controlling these pests.

MISCELLANEOUS.

The interest aroused by the work of the station on kukui oil obtained from seeds of *Aleurites triloba* is shown by the requests which have come from the mainland and from various European countries for kukui nuts and oil for commercial use. There seems to be an active demand for this oil. About thirty-five paint and varnish firms have stated that they would like to buy this oil, some of them to the extent of 25,000 barrels a year. There has been considerable local interest in the kukui industry. Preliminary surveys have been made to determine the amount of nuts available, and one small plant was erected for expressing the oil. It was found in this plant that 40 gallons of oil could be obtained from a ton of nuts. This amount agrees closely with the results obtained in the laboratory at the station. A company is now being organized to express the oil. One New York firm is looking into the business with the idea of securing all of the available kukui nuts in the Territory for oil production. On account of the high value of the press cake as a fertilizer, it would seem best for the Territory that the oil be expressed in Honolulu. The press cake would thus be maintained as fertilizer, and a considerable amount saved on shipments made to New York.

The use of algaroba meal, the ground pods of *Prosopis juliflora*, is rapidly spreading throughout the Territory. The business now amounts to about $350,000 a year. The supply of algaroba beans, while larger than was at first anticipated, is not sufficient for local demands. There is no necessity, therefore, for seeking an outside market for this material. Some of the ranchers and dairymen are preparing to put up plants of their own. For this purpose a drier recently devised by G. F. Winter, of Lihue, Kauai, will be used. An ordinary alfalfa meal mill will grind the algaroba beans very satisfactorily after they have been dried. The Army in Hawaii uses algaroba meal as one-quarter of the grain ration for horses and mules. The interest in this feed is generally more active than has heretofore been the case. As a result of this increased interest there is little of the product which is allowed to go to waste. On some of the large estates the right to pick algaroba beans for a period of ten to fifteen years has been secured.

The experiments carried on by this station and elsewhere with arsenite of soda as a chemical spray for the destruction of weeds has brought about the general use of arsenite of soda for destroying weeds on rubber plantations and on many of the ranches. During the past year this spray was tested on many of the sugar plantations with excellent results and with a great saving in the cost of weed destruction. Several other plantations are now preparing to use the remedy extensively. On one large sugar plantation it has

been estimated from this year's work that the saving in cost of weeding alone has been about $100,000. In some of this work the formula used by the station has been modified to the extent of using caustic soda in the place of carbonate of soda to combine with the arsenic. The station is carrying on experiments to determine the fate of arsenite of soda in the soil and its possible effect upon nitrification and upon the physical properties of the soil. In pot experiments when arsenite of soda was added to the extent of 0.25 per cent of the soil, it was found to cause a pronounced deflocculation. The amounts used for spraying purposes thus far have showed no effect upon the soil.

In addition to breeding work with papayas the station has investigated the matter of producing papain. It was found that dried papain can be produced at a profit for about $2.50 a pound. Requests have recently been received for 2,000 pounds of the material at that price. A papaya grower on Maui is preparing to produce the material. In experiments at the station it was found that if in the early morning a dozen shallow lengthwise incisions, one-half to three-quarters inch apart, are made in a papaya fruit of good size, enough juice will be obtained to make half an ounce of dry papain. Fruits may be tapped on alternate days five to seven times in all. As soon as the fruit begins to turn yellow the milky juice flows less freely. The tapping wounds heal quickly and the fruit is not injured by tapping; in fact, the flavor appears to be somewhat improved, since a slight bitterness which characterizes the juice is thereby removed. It has been found that the papain is injured if the juice is allowed to come in contact with any metallic substances. The only precautions to be observed are that tapping be done with a glass, bone, or ivory instrument, and that the juice be collected in china or earthenware containers, and promptly dried. From the work along this line at the station it is estimated that papain to the value of $2 can be taken from each tree annually.

The use of dynamite for agricultural purposes, particularly in improving soil conditions continues to increase. The results obtained from dynamiting pineapple plantations at the end of the first picking season are satisfactory. The extended commercial experience indicates that dynamite, to be most effective, should be used when the soil is not too moist. If a charge of dynamite is exploded in a wet subsoil it has a tendency to form a more or less spherical cavity in the soil, packing the soil about the walls of the cavity without shattering the surrounding soil sufficiently. The use of dynamite in lawns is increasing. Many lawns which have stood for years without renovation show poor growth of grass on account of the extreme packing of the soil. Dynamite can be safely used in lawns for loosening the subsoil below and improving drainage.

The station has advocated since its establishment thirteen years ago the general use of legumes for green manuring in all branches of agriculture in Hawaii. Experiments have been carried on continuously with different legumes to learn what species were best adapted to practical use in the Territory. Among the generally cultivated legumes jack beans and lupines have proved most satisfactory. The German lupine has given excellent results at the station and elsewhere. Jack bean has the advantage of being a rapid and vigorous grower, and also of being relatively immune to plant lice and other insects which may check the growth of cowpeas. If the cowpeas were not so highly susceptible to the attack of aphids, it would be the legume to be recommended for green manuring. Under local conditions, however, jack beans or lupines or Mauritius bean must be considered most promising. For several years this station has been experimenting with an introduced leguminous weed known as rattlepod (*Crotalaria saltiana*). This legume is unusually hardy. It thrives in wet or dry districts. It will make a fairly good crop under rainfall of 20 inches and thrives abundantly under a rainfall of 200 inches. The seed will germinate promptly with little attention after scattering broadcast upon the soil. The plant is not useful for feed, but is an excellent green manuring crop. No insects do any harm to the plant except the blue butterfly, which merely reduces the number of pods. The seed of this plant can be readily obtained by offering children 10 cents a pound for it. Some of the independent cane planters, as well as the larger plantations, already have standing offers of 5 to 10 cents a pound for Crotalaria seed to be collected from the roadsides and elsewhere by women and children. The seed can not be obtained through seed dealers, but the supply to be obtained from waste places seems to be adequate for present purposes. The Crotalaria has the advantage over cultivated legumes that the seed may be sown without any previous preparation of the soil and of course without cultivation after seeding. In old cane fields, after the last ratoon crop is removed, the trash may be allowed to remain, as well as all weeds which naturally spring up. In order to increase the amount of plant material in the soil Crotalaria seeds may be scattered among the trash and weeds and even under these conditions the plant will make a satisfactory growth. The demand for jack-bean seed is increasing rapidly. The price offered is 5 cents a pound in ton lots. The supply is quite inadequate, but a number of homesteaders are preparing to grow the seed for neighboring plantations.

As already indicated, legumes are coming into use on sugar plantations to supplement the amount of humus derived from trash. The tendency at present is to abandon the burning of cane trash and to allow all this material to rot on the soil or to plow it under. The

results obtained from this economic use of humus material are so apparent that the practice of burning will probably be abandoned altogether within a few years. On several plantations fields which had become the poorest on the whole plantation gave the largest yield during the past year as a result of plowing under humus-forming material, but without applying excessive amounts of commercial fertilizers.

Analyses were made of samples of coffee from coffee cherries uninfested with fruit fly, badly infested with fruit fly, and also from half-ripe cherries taken four or five days before they would be completely ripe. No chemical differences in the composition of the coffee were noted in these different samples. Coffee was prepared for drinking, however, from all the different samples by three different methods, and the coffee was submitted to several persons for their opinion as to the flavor and other qualities of the different samples. All persons to whom the samples were submitted agreed that the sample from infested fruit was slightly insipid and poor in quality, while that from the fruit not quite ripe was pronounced best in flavor. The only explanation which can be suggested at present for this is the fact that the half-ripe fruit comes to the mill in an uninjured condition, while the cherries from ripe and partly infested fruit are nearly all ruptured and in process of fermentation. The fermentation of the whole cherry rapidly develops a putrefactive odor which apparently affects the flavor of the berry injuriously. As a result of these findings coffee growers are picking their fruit a little greener than heretofore, and are thus securing coffee of better flavor and avoiding the excessive infestation of the fruit fly.

A further test was made to determine whether infestation with the fruit fly might cause a loss of weight in coffee. Using the same number of coffee berries from infested and uninfested fruit it was found that the weight of berries from infested fruit immediately after pulping was 5 per cent less than that of berries from uninfested fruit. The first weight was taken after pulping and allowing the parchment to become dry on the outside. Weighings were made from time to time after removing the parchment and silver skin. It was soon observed that the weights of the two lots of berries began to approach each other. When the coffee came to a constant weight and was considered dry the weights of the two lots were the same. It would appear, therefore, that little or no loss of weight in the coffee berry is caused by infestation of the fruit fly.

An unusual amount of damage from rats on the island of Molokai led to a test by the station of the value of a rat virus in destroying this pest. The virus was distributed about a year ago. Dead rats were found within a week or two near all the points at which the virus was

distributed and have been found whenever search was made up to the present time. Apparently the infection has persisted for a whole year with the result that the number of rats has been reduced about one-half. No evidence has appeared that this disease which persists among rats can infest other animals.

Experiments are now in progress to determine the applicability of cold storage to various tropical fruits. It has already been found that holding fruit infested with the fruit fly for a period of ten days at a temperature of 32° F. destroys the fruit fly in whatever stage it may be present. Perhaps cold storage will be accepted as a sufficient means of rendering fruit such as avocados safe for importation into the United States. It has been demonstrated that avocados may be held without injury to the fruit at a temperature of 32° F. for at least two months. The same has been found to be true for star apples and water lemons. Figs have been held for one month at 32° F. with beneficial results to texture and flavor of the fruit. Pineapples came out of a month of cold storage at 32° F. with excellent flavor. The only fruits which have thus far shown a tendency to absorb a disagreeable cold-storage flavor are papayas and mangoes.

Frequent attempts to produce alfalfa hay in Hawaii have yielded rather unsatisfactory results. It seems impossible to secure a good quality of hay. Usually, alfalfa can not be dried in the open air in Hawaii so that it will not heat and mildew when stored. Plans are now being made to dry alfalfa by the devices which are already used for drying algaroba beans. A test of one of these machines on a small scale produced an excellent quality of alfalfa hay which was later ground into meal. The meal was greener and less bleached than the ordinary alfalfa meal imported from the mainland.

A disease of bananas has been observed in Hawaii for many years and has sometimes been mistaken for the Panama disease. It, however, obviously differs from the Panama disease. Infested leaves show spores of a Fusarium, and at the border line between healthy and diseased tissue a bacterial organism was found by Dr. H. L. Lyon in nearly pure cultures. The most obvious symptom of this disease is the death and decay of the terminal young leaves or at least a yellowing and wrinkling of these leaves. Infected plants do not produce the ordinary large leaves, but narrow, yellow, wrinkled ones. Small distorted bunches of fruit may also be formed. These bunches do not fill out properly. It has been found that where the disease is neglected it may gradually become more serious and infect a large percentage of the plants on a given plantation. Spraying with fungicides appears not to be effective, since the fungus is already within the tissues of the plant before the disease can be detected by its symptoms. If, however, diseased plants are cut out and destroyed by fire as soon

70966°—15——4

as they are noticed the disease can be cheaply and effectively held under control. The disease in question seems to affect chiefly the Chinese banana.

During the past year the hen flea (*Sarcopsylla gallinacea*) appeared in Honolulu and has been spreading rapidly. It is found on chickens, rats, cats, and perhaps other animals, and a bad infestation may kill the young chickens. The fleas are similar to the dog flea and have the habit of burying their heads in the skin of young chickens about the eyes and neck and under the wings, where they remain attached like ticks. A number of remedies were tested in attempts to destroy this pest of young chickens. The remedies included carbolated vaselin, containing 2 per cent of carbolic acid; kerosene; zenoleum in a 3 per cent solution, and carbolic acid in 1, 2, and 3 per cent solutions in glycerin and water. The remedies were applied to the heads of young chickens by means of a small brush. The hen flea is evidently very resistant to contact insecticides. About 75 per cent of the fleas were killed with a single application of kerosene. All of the fleas were killed by an application of carbolated vaselin and a 3 per cent solution of carbolic acid. Zenoleum in a 3 per cent solution was about as effective as kerosene. The pest is found in the soil about infested yards and in cracks of buildings. The trouble is so serious that poultry raisers should thoroughly spray infested yards. Since rats may also carry these fleas, this constitutes one more good reason for a warfare on rats.

During the year the following publications were issued by the station:

Annual Report for 1913.
Bulletin 29, Ornamental Hibiscus in Hawaii.
Bulletin 30, The Effect of Heat on Hawaiian Soils.
Bulletin 31, Rice Soils of Hawaii.
Bulletin 32, The Papaya in Hawaii.
Bulletin 33, The Organic Nitrogen of Hawaiian Soils.
Bulletin 34, Tobacco Insects in Hawaii.
Press Bulletin 45, An Experiment in Marketing under Territorial Auspices.
Press Bulletin 46, Poultry Management.

REPORT OF THE CHEMICAL DEPARTMENT.

By W. P. Kelley.

The work of the chemical department has been continued along the lines mentioned in the last report. The great importance of soils and the many practical difficulties and great expense now incurred in their management and fertilization are sufficient reasons for devoting much study to this subject. The efforts of this department, as in previous years, have, therefore, been devoted mainly to soil investigations. In view of the limited state of knowledge concerning soils and the fundamental importance of the subject, it has been deemed wise to devote considerable time to the investigation of problems of a scientific rather than of a practical nature. In this work effort is being made to find the reason for some of the soil processes that are now only imperfectly understood and to render the common soil practices more intelligible. In this connection studies were undertaken on the bacterial processes of soils, on the physical effects of fertilizers and other chemical substances, and on the availability of phosphates. In addition, a study on the composition of tropical fruits in the islands has been completed, and at present an investigation of the organic phosphorus of rice is being made. A limited amount of time has been devoted to miscellaneous analyses.

BACTERIOLOGICAL INVESTIGATIONS.

The availability of nitrogen in soils is of great importance. There are many forms of nitrogen in soils which previous investigations have shown to be available to plants. Most of these arise from vegetable proteins by the action of bacteria, and are susceptible of further decomposition. Usually investigations on this subject have dealt with ammonification, nitrification, denitrification, and nitrogen fixation, without giving much consideration to the intermediate changes between the complex proteins and the end products. However, since different organic nitrogenous fertilizers become decomposed and converted into ammonia and nitrate at different rates, and in view of the fact that different proteins yield different amounts of hydrolytic products which are of unequal availability and which probably undergo further decomposition at different rates, it is a matter of interest to follow the course of the changes taking place.

The initial decomposition may be assumed to be of a hydrolytic nature and probably to result from the action of bacterial enzyms, but whether *deamidization* is a hydrolytic or oxidative process remains to be determined. From previous work on the organic nitrogen of Hawaiian soils it was suggested that bacteria cause a more rapid decomposition of the diamino acids than of the other groups present in proteins. Extending these investigations to include a study of the bacterial decomposition of nitrogenous fertilizers, it has been found that the basic nitrogen compounds (diamino acids) actually disappear more rapidly than the other groups. The work is being continued with the use of pure proteins.

Closely related to the hydrolytic decomposition of proteins in soils is the ammonification of the hydrolytic products. Investigations will be undertaken on the ammonification of the more common amino acids and acid amids of protein cleavage. In this work special study will be given to the amino acids as sources of energy to bacteria as well as to determine the ammonia formed.

PHYSICAL STUDIES.

Evidence has been accumulated in recent years on the importance of physical factors in soils. From the work in this laboratory and the experience of farmers it is certain that physical factors play a very large part in Hawaiian soils. Soil films and colloids especially appear to play an unusually prominent rôle in their fertility. The striking effects of heat on the growth of plants, the high power for absorbing fertilizers, the importance of aeration, the abnormal effects of lime, and the influence of volatile antiseptics, all seem to be related to colloids. The data already obtained in studies on these subjects emphasize the need for much further study along these lines.

As bearing on these subjects, an extensive series of experiments has been carried out on the moisture relations in soils as affected by fertilizers. Such phenomena as capillarity, percolation, flocculation, cohesion, specific gravity, vapor pressure, and hygroscopic moisture have been studied and an unusually large array of data obtained. A number of different soil types were used and very striking results obtained. It has been conclusively demonstrated that fertilizers do exert measurable physical effects and that there are physical pecularities in Hawaiian soils not hitherto met with. In general, it may be said that no two of the different soils studied were affected to the same degree, and frequently not even in the same order, by a given fertilizer.

The results obtained still leave the subject in an uncertain state. The data must be considered to be empirical, and the conclusion drawn as tentative only. Nevertheless, progress has been made.

The subject is one of unusual complexity and will require the patient efforts of years for its elucidation. However, the conclusion seems to be justified that film pressure and colloids are very important phases of Hawaiian soils, and are affected by fertilizers in some instances to a striking degree. The results of this investigation are being prepared for publication by Mr. McGeorge, assistant chemist.

THE AVAILABILITY OF PHOSPHATES.

Experiments have been in progress for more than a year on the availability of phosphates. This work was undertaken in cooperation with the basic slag committee of the Association of Official Agricultural Chemists, but in view of the practical interest in the subject, the work is being extended to include a wide range of phosphates, using a number of soil types and crops. Hawaiian soils contain abnormal amounts of iron and alumina and are able to absorb unusual quantities of soluble phosphates. Consequently, the availability of phosphates is a question of special interest.

The results to date show that different crops vary greatly in regard to the effects produced by different phosphates. Immediately following the application, different soluble phosphates seemed to affect the growth of millet similarly, while insoluble forms were ineffective. After remaining in the soil some months in conjunction with decaying organic matter, however, rock phosphate became as effective as soluble phosphates, and both forms then gave marked increases in growth. In this work such questions as the reversion of soluble phosphates by lime, the lasting effects of phosphates, the absorption of phosphate by the plant, and the effects of decaying organic matter on availability are being studied.

THE COMPOSITION OF HAWAIIAN FRUITS.

The composition of tropical fruits is a subject of much interest. A number of analyses of such fruit have previously been made, but frequently of fruits that had been shipped over long distances after having been picked. With few exceptions, there are no records of the composition of Hawaiian fruits. Therefore, it was deemed wise to analyze the fruits growing in the islands. In this work the different fruits were allowed to ripen thoroughly on the tree, and were analyzed immediately after picking. The results obtained are therefore of special interest as showing the composition of a large number of normally ripened fruits. A study of the changes taking place during the ripening of bananas and papayas was also made. The results are given elsewhere (see p. 73).

THE ORGANIC PHOSPHORUS OF RICE.

The mineral constituents of foods and feeds are coming to be more seriously considered in nutrition. Among these constituents phosphorus is of especial interest. This element has long been known to occur in plants in both organic and inorganic combinations, but the specific phosphorus compound occurring is a matter of uncertainty. Aside from lecithin and inorganic phosphates, very little until recently was definitely known. From the work carried out at the New York State station and elsewhere, it appears that wheat, oats, corn, and cottonseed meal contain rather large amounts of phytin. In view of the great importance of rice as a food, a study of the forms of phosphorus contained in it is of special interest. This work was undertaken near the close of the year, but interesting results have already been obtained.

REPORT OF THE ACTING HORTICULTURIST.

By C. J. Hunn.

J. E. Higgins, the horticulturist of the station, was away during the past year on leave of absence. V. S. Holt and the writer carried on the work as outlined at the beginning of the last year, and attempted but few new lines.

PAPAYA INVESTIGATIONS.

This station has received during the past two years seeds of many varieties of papaya, *Carica papaya.* These seeds have been planted and many of the seedlings are growing at the station. Others have been distributed among private individuals. In the latter case, the station reserves the right to select the best trees and to propagate from these superior varieties. Many of these trees are now coming into bearing.

Mr. Holt has presented elsewhere [1] a more complete report of the types of papaya flowers and fruits found in the F_2 generation of No. 3198, which were grown from two hermaphrodite flowers fertilized with their own pollen. At the time the report was written only 343 trees were old enough to exhibit sex and fruiting characteristics. There are now 454 trees which show the following types:

Types of papayas grown from close fertilized fruits.

Form No.	Character of fruit.	Number of trees.
1	Pistillate	164
1 and 7	Pistillate and pentandria	1
1, 4, and 9	Pistillate, elongata, and intermediate	2
1, 4, and 7	Pistillate, elongata, and pentandria	2
4	Elongata	108
4 and 9	Elongata and intermediate	2
7	Pentandria	1
8	Pentandria and elongata	148
7, 4, and 9	Pentandria, elongata, and intermediate	5
9	Intermediate	0
2	Staminate	16
3	Correæ	5
	Total number of trees	454

The main object in the breeding and selection of this type of papaya is the elimination of the staminate plants. These 454 trees may be grouped as follows:

	Per cent.
Fruit bearing, exclusive of correæ	95. 37
Correæ	1. 1
Staminate (sterile)	3. 52

[1] Hawaii Sta. Bul. 32, pp. 34, 35.

Since with the diœcious type of papaya, one theoretically expects 50 per cent fruit bearing, the attainment of over $95\frac{1}{3}$ per cent fruit bearing, exclusive of correæ, is a great step in the elimination of the staminate type.

Contrary to expectations, the elongata type has increased in percentage, which gives promise of the ultimate development of a pure strain of uniformly cylindrical fruits. Since this type exhibits general uniformity and is of excellent quality, the work in the future will deal strictly with the elongata type and with the elimination of all the other types of flowers and fruit.

CHANGE OF SEX IN THE PAPAYA.

As noted in a previous publication,[1] the forms of the papaya tend to be variable. The staminate flower of the male trees possesses an undeveloped or abortive pistil. Several authenticated cases of the complete change of a male tree to one purely female have been presented in scientific publications. Previous to this time the station has been unable to present favorable evidence on this point from experiments actually performed in the station's orchards. Early last summer Mr. Holt removed the tops of 22 sterile staminate trees. These trees all made considerable growth and now show the following characteristics: Sterile staminate, 18; correæ, 2; pistillate, 1; and elongata, 1.

The large percentage of sterile staminate trees may be due to the fact that the larger number were of the type of papaya which, under normal conditions, produces equal numbers of staminate and of fruit-bearing trees.

The two staminate trees that changed to correæ appeared in variety No. 2978, in which there are 56.25 per cent pistillate, 12.50 per cent correæ, and 31.25 per cent sterile staminate. The two trees that made the complete change in sex from sterile staminate to one pistillate (see Pl. I, fig. 1) and one elongata, appeared in the F_2 generation of No. 2355:1, in which there are 95.37 per cent fruit bearing and only 3.5 per cent sterile staminate. The two trees that changed sex were the only trees of this type that had been beheaded. As has been noted,[1] there are several possible hypotheses which may account for this change. At present, the only possible explanation of these changes in sex is that there is a preponderant tendency to fruit bearing in No. 3198 and a like tendency to the correæ form in No. 2978.

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[1] Hawaii Sta. Bul. 32, pp. 25–27.

MANGOES AND AVOCADOS.

The mango and avocado orchards have been gradually coming into bearing during the past several years. Figures on the bearing age of the various types of trees are as follows:

Bearing age of mango and avocado trees.

	Number of trees.	Average age at time of bearing.		Number of trees.	Average age at time of bearing.
Mangoes:			Avocados:		
Seedlings	48	6 yrs. 3 mo.	Seedlings	27	7 yrs.
Budded	15	3 yrs. 8 mo.	Budded	11	2 yrs. 11 mo.
Inarched	11	2 yrs. 10 mo.			

BAGGING OF FRUIT.

Since the advent into these islands of the Mediterranean fruit fly (*Ceratitis capitata*) many kinds of fruit, on approaching maturity, have been covered with heavy paper bags (Pl. I, fig. 2). The larvæ of *Amorbia emigratella* and of *Cryptoblabes aliena* cause considerable trouble by weaving their webs among the terminal leaves and the flowering panicles of the mango. In order to secure the best fruit it is necessary to remove such webs, as well as diseased and misshapen fruit. While performing these operations but little additional effort is required to place and tie a bag over each fruit cluster. The individual fruits ripen more uniformly but lack the color of those exposed to the sun. Several varieties of the Indian mango have been found to be practically immune to the attacks of the fruit fly.

HIBISCUS.

This station participated in the hibiscus show held during the Mid-Pacific Carnival Week in February, at which time the station's exhibit of varieties, which consisted of Mr. Holt's personal collection of imported and original varieties and those which he has since originated, was unanimously granted the first award. This recognition of the station's collection has created a demand which has been filled in part by the distribution of over 30,000 cuttings and seedlings during the past three months. Mr. Holt has selected the best varieties of hibiscus, and some 200 grafted plants are now being grown in soy tubs for exhibition purposes.

Mr. Holt has outlined a number of experiments in the breeding of hibiscus, one of which is worthy of mention. Yellow hibiscus are exceedingly rare. The process of crossing adopted by Mr. Holt has given a clue as to how this color may be developed. A single orange hibiscus with upright stigmas (39:1) was introduced several years ago from Germany. The F_1 generation (145:1) was self-fertilized

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and produced a flower much like its parent. This F_1 hybrid was crossed with 1E (533:1),[1] a single pale cerise flower with white veins and throat and a pale yellow column. The resulting cross, F_2 (102:2), has pale crimson petals with light veins, a dark crimson eye and upright stigmas. The F_2 cross was self-fertilized to produce F_3 (395:1) V. S. H. Parents 1E×Single orange (upright).

The new variety may be described as follows:

Moderate growth, freely branching, brownish bark, green twigs, good foliage.

Leaves ovate, acuminate, serrate, nearly smooth, dark green, $1\frac{1}{2}$–2 inches wide, $2\frac{3}{4}$–$3\frac{1}{2}$ inches long, petiole $\frac{3}{4}$–1 inch long.

Flower 5 inches wide, scarlet orange with yellow veins, crimson eye, column yellow, crimson at the base, stigmas crimson, appressed, peduncle 2 inches long, bracts 6, green, not spreading, self-seeder.

This hybrid, No. 395:1, has been self-fertilized and also used as the male or as the female parent in a large number of crosses, the seedlings of which will be grafted on thrifty stocks to hasten their flowering.

NEW PLANTS.

A number of years ago the station collected in Honolulu several slabs of an almost spineless cactus. Dr. W. T. Brigham states that he has known this cactus for a long time and that he believes it was introduced by Don Marin. Dr. Brigham suggests that this cactus be called "The Manini Cactus" (the Hawaiian form of Marin). These cactus slabs were grown into plants, which after subsequent subdivision have developed into a hedge nearly 100 feet long. A description of the plant is given herewith:

OPUNTIA.—Plant averaging 6 to 8 feet in height, shrubby and much branched; basal slabs forming the trunk, averaging 10–14 inches long, 5–6 inches wide, $1\frac{3}{4}$–$2\frac{1}{4}$ inches thick, joints 2–$2\frac{1}{2}$ inches in diameter, smooth and deep green in color, becoming rough and grayish at the joints; mature slabs 10–14 inches long, 4–5 inches wide, $\frac{3}{8}$–1 inch thick, narrowing slightly toward the center of the slab, obovate in form, olive green, and inclined to be slightly woody; immature slabs 8–10 inches long, 3–$3\frac{1}{2}$ inches wide, $\frac{1}{4}$–$\frac{3}{8}$ inch thick, obovate, pea green, and very fleshy; spines absent or at times small and inconspicuous; after being developed into short fleshy leaves, sometimes with spiny terminals, these appendages fall as the slabs mature; when present these spines are two in number, $\frac{3}{32}$ inch long, light gray below, brownish at the tips; spinules absent or very small and basal, 2 to 3, grayish; spinules are numerous and very small in areoles on the fruit; flowers are borne singly at the tips of young branches and consist of a modified joint, bearing at the apex the floral portions, the ovary being buried in a slight depression in the joint; basal joint $1\frac{1}{2}$ inches long, $\frac{7}{8}$–1 inch wide, pear-shaped to globose, green, areoles bearing numerous small spicules, floral portion $1\frac{1}{2}$ inches long, $1\frac{1}{4}$ inches wide, never spreading; petals averaging 25, outer ones short and fleshy, inner ones long and thin, rose to pink in color; stamens and filaments averaging about 300, filaments $1\frac{3}{4}$–2 inches long, yellowish at the base, carmine above; stigma and style green, stigma 7 parted; style 2 inches long; ovules numerous and contained in the fleshy fruit; the joint changes to a succulent and juicy fruit,

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[1] Hawaii Sta. Bul. 29, p. 42.

FIG. 1.—STERILE STAMINATE PAPAYA TREE CHANGED TO PISTILLATE BY BEHEADING.

FIG. 2.—MANGO, SHOWING FRUITS COVERED WITH PAPER BAGS.

FIG. 1.—OPUNTIA, AN ALMOST SPINELESS CACTUS.

FIG. 2.—CLAUSENA LANSIUM, WAMPI.

1½–2 inches long, 1–1½ inches wide, pear-shaped to globose, areoles with numerous small spicules, claret red; pulp deep claret red, many seeds, watery and almost tasteless.

Rapid growth, very productive, and best propagated from slab cuttings, since seed are liable to be cross-fertilized with the spiny Opuntias.

Since this cactus is of rapid growth and comparatively free of spines, it is worthy of attention as an ornamental hedge and as a fodder plant. (Pl. II, fig. 1.)

One of the little-known fruit plants introduced from China is the wampee, whose edible berries are highly esteemed by the Chinese and others. There are about a dozen trees in bearing in Honolulu.

Clausena lansium; C. wampa or *Cookia punctata.* Wampee or wampi. Aurantiaceæ. (Pl. II, fig. 2).—A small tree, 18–20 feet, with luxuriant foliage, native of South China; nearly glabrous pinnate leaves; small dense panicles of whitish sweet-scented flowers, produced in April; fruit ripens in June and July; an edible berry, borne in clusters like the grape, individual fruit nearly globose, the size of a large marble, rough, tough, orangelike rind pale straw yellow in color and covered with glands full of green balsamic oil; seeds 1 to 3 nearly filling the fruit cavity; a small quantity of almost colorless juicy pulp between the seeds and the rind, with an agreeable, aromatic acid taste.

Propagated by seeds and layers. Often used as a dessert fruit, but mostly for preserves. The leaves are used in flavoring. This fruit is subject to the attacks of the fruit fly and should be covered with paper bags.

THE PINEAPPLE SEEDLINGS.

The pineapple seedlings Nos. 3059 and 3060,[1] were transplanted last October from quart tins into 12-inch flower pots. Since the pineapple plant is greatly influenced by the physical character of the soil, considerable black sand was incorporated into the soil mixture. There were 48 plants in lot No. 3059, of which 31 plants are now growing. These plants vary from 1 to 8 inches in height and from 1½ to 14 inches in the spread of the foliage. In character they may be listed as excellent 1, fine 5, good 8, fair 8, poor 8, and very poor 1; no spines 4, very few spines 11, few spines 5, and very spiny 11. There were 53 plants in lot No. 3060 of which 41 plants are growing. These plants vary from 1½ to 12 inches in height and from 2 to 23 inches in the spread of the foliage. In character these plants may be listed as excellent 6, fine 8, good 9, fair 10, poor 5, and very poor 3; no spines 8, very few spines 13, few spines 1, and very spiny 19. In color the leaves of these seedlings vary from green to red and bronze, either as a solid color or in stripes. A number of these seedlings give promise of developing into superior plants and will later be planted under field conditions in order that the character of fruit may be ascertained.

[1] Hawaii Sta. Rpt. 1913, p. 23.

THE PROPAGATION HOUSE.

The solar heater which was originally installed in the propagation house when the latter was reconstructed proved satisfactory only during the afternoons of sunny days. A small gas heater and a water boiler were placed in the propagation house. The hot water did not circulate as rapidly as desired and the benefits were not commensurate with the amount of gas consumed. The plan of having the hot-water pipes in direct contact with the sand also proved unsatisfactory because the sand acted as a nonconductor of heat. The water pipes have been placed in an inclosed chamber just below the sand bed. A concrete pit has been constructed at one side of the propagation house, inside of which has been installed a large gas heater, thermostat, and a boiler. Other appliances, such as water, gas, and safety valves and an auxiliary water container, have been placed in position. Preliminary experiments have proved that this arrangement is efficient, but further work is necessary before definite conclusions may be drawn.

FIELD WORK.

The usual field work of this department has occupied considerable time. The various orchards have been pruned, fumigated, and given general cultural attention. Cover crops were sown at the proper season and were later turned under to maintain the fertility of the land.

ACCESSIONS.

Among the accessions of the past year which are worthy of note are several species and a number of varieties of papaya; budwood of selected local and California varieties of avocado; budwood of the Carabao and Pahutan mangoes; a variety of cucumber with a thick, almost reticulated rind, which is said to be somewhat resistant to insect pests; a species of pipe gourd; a collection of 12 varieties of spineless cactus; several new varieties of sweet potatoes; two new varieties of roselle; and plants of *Lansium domesticum* and three varieties of Garcinia.

This station receives frequent requests for assistance in the selection of agricultural materials. In order to be prepared for such demands, there has been gathered together an excellent collection of American and foreign seed and plant catalogues, spraying machinery and spraying-materials catalogues, farm-machinery catalogues, and catalogues of horticultural tools and requisites.

DEMONSTRATION AND DISTRIBUTION.

There has been an unusual demand for advice and assistance from those interested in homesteads. While this department makes no pretense of keeping a stock of plants and seeds on hand for distribu-

tion, many of these requests have been filled. The principal plants distributed this past year have been seeds and plants of the papaya, the Kusaie lime, and the rough lemon. The quantity of budded citrus and budded and grafted avocados and mangoes has not been sufficient to supply the sale demands. This department has from time to time filled requests made by other scientific institutions.

NEEDS.

The horticultural department is in need of a rat-proof room for the hardening off of new potted seedling plants, a more effective and permanent soil sterilizer, and a large storage space for tin cans and seed flats.

In closing it is desired to express appreciation of the faithful and efficient services of Valentine S. Holt, acting assistant horticulturist, James H. Cowan, assistant, and of those who have done the detail work of the propagating house and orchards.

REPORT OF THE AGRONOMY DEPARTMENT.

By C. K. McClelland and C. A. Sahr.

Work in this department for the year has been carried on along much the same lines as in previous reports. Taken altogether, the results obtained have not been entirely satisfactory on account of weather conditions and pests. The most complete failure was with corn. Corn was planted in November following several good rains, and grew well from the start. Severe winds during January whipped the plants so badly when they were in tassel that no grain was produced. In a plat in which germination was tardy and the plants less advanced, a better result was obtained.

RICE.

The work with rice is being continued on a small scale in Nuuanu Valley. The lines of work include trials of varieties, aeration of the soil previous to planting, rotation, green manuring, and fertilization. Fertilizers have given no definite results on this land for the past two crops, probably due to the richness of the soil. These plats had not been planted for several years, and a considerable amount of grass and roots was turned under in preparing the land for cultivation. The two following varieties have been grown for the first time during the past year:

Bezembo, a Japanese variety obtained from James Armstrong, of Pearl City, and which is grown quite extensively by him. It was brought from Japan by some of his laborers, and it is preferred by them to the Shinriki variety which Mr. Armstrong has also grown from paddy furnished by this station. In the fall of 1913 it yielded about the same per acre as did Shinriki, but slightly less than did Omachi. It blooms and matures in about 10 days less time than either of the other varieties named.

Long Nyah Yin is a Chinese variety obtained from the Oahu Rice Mill Co. It is a short kernel variety and considerably later than the Japanese varieties. However, the Chinese claim that it will produce two crops. It is also said to be as well or better adapted to salt marsh lands as the No. 19 variety heretofore grown on such lands.

The importation of rice into Hawaii continued at about the same rate, the amount for the fiscal year ending June 30, 1912, being

30,000,000 pounds of rice in the brown; for the year ending June 30, 1913, the amount was 32,000,000 pounds. The shipments from Hawaii to the United States during the calendar year of 1912 were 471,793 pounds, and during 1913, 479,920 pounds. The shipments from the United States to Hawaii during the same years were 52,705 and 319,975 pounds, respectively. The shipments to the United States were mainly of Chinese and Hawaiian rice, while those to Hawaii from the mainland were mainly of Texas-grown Japanese rice. In addition to these shipments, the Quartermaster's Department of the United States Army brought in, during the year ended May 1, 1914, 183,000 pounds, previous to which date their supply was obtained locally. The increase of shipments from the United States in more recent times would seem to indicate that many of the Japanese population have concluded to eat more of the cheaper American rice and less of the imported dearer kinds.

SMALL GRAINS.

Wheat, oats, rye, and barley were planted on limited areas. The wheat rusted badly, and although a few heads matured, the results are such as to hold out little hope of successful wheat raising under local conditions. Rye did excellently at first, and more completely covered the soil, and at an earlier date than did any of the other small grains. While the stand was perfect, when the grain headed out, the appearance was that of a thinly planted plat—the number of heads being about 30 per cent of what they should have been. Oats did better than during the previous year, and averaged, when headed out, about 45 inches in height. As with rye and wheat, the number of heads formed was a very small percentage of what one would term a good crop. Oats at the station make rather a slow growth, and lodge badly before maturing. The wide-leaved varieties are particularly subject to rust.

Barley, though slow in its early growth, headed out better than either oats or rye. Both varieties grown headed at the same time, matured in 150 days, and made a growth of 34 inches. The success of this crop is still uncertain, and further trial is required.

The small grains are attacked by rice birds and sparrows, and with these pests in abundance it is impossible to obtain any accurate data upon seed production.

SORGHUMS.

In an experiment with a sweet sorghum, a nonsaccharine sorghum, and Japanese cane for yields of forage over a long period, the sweet sorghum has yielded, in four cuttings, 47.1 tons per acre, and the nonsaccharine variety 49.8 tons in three cuttings. The Japanese cane cut for the first time yielded 102 tons of forage per acre 453 days

after planting. The testing of several varieties of African sorghums for the Office of Forage Plant Investigations at Washington has been attended with some difficulties, such as flood, drought, and severe checking of soil, and the attack of birds. Because of unthriftiness, the first planted sorghums were cut back about September 1, and the ratoon crop allowed to produce seed in the late fall and winter. Because of birds no heads except those covered with wire cloth (held on with spring clothespins) matured, and for that reason very few and often imperfect heads were available for shipment to Washington. A duplicate planting was made on the Wyllie Street plats in October, but these did not reach normal size—heading out early because of cool weather.[1]

SUDAN AND OTHER GRASSES.

Sudan grass planted November 22, 1913, did excellently well. The first cutting, on March 9, 1914, yielded at the rate of 31 tons per acre of green forage; the second cutting, made May 8, was at the rate of 30 tons. The stems of Sudan grass run quite uniformly small and with wide leaves, although occasional plants show a coarseness of stem. The quality of the grass could probably be maintained and improved by roguing out these coarse stemmed plants as fast as they are found, to prevent cross-pollination and consequent deterioration of the seed. With Tunis grass, on the contrary, there is more variability. The majority of the plants have a stem slightly larger than that of Sudan grass, but the leaves are much narrower, and there are many variations with coarse stems and wider leaves. (Pl. III, fig. 2.) Sudan grass is much superior at lower, and Tunis at higher, elevations. At Schofield Barracks the Quartermaster's Department put in about four acres of the Sudan, this being the largest planting as yet made in the Territory. The agronomy department has distributed seed in small amounts to some 40 farmers on the several islands.

New pasture grasses that may prove to be of some value upon lower lands with light rainfall are: Teff grass (*Eragrostis abyssinica*), *Chrysopogon montanus*, and Giant Bermuda. The latter grass has larger stems and leaves and grows more rapidly than does the ordinary manienie. *Chrysopogon montanus* is a perennial grass which has a habit of growth very similar to pili (*Heteropogon contortus*) and it will probably be one of value in the pili country. It will

[1] These long season nonsaccharine varieties of sorghum rarely head out during the warm summer months but seed freely in the cooler fall, winter, and early spring months. No. 309 (S. P. I. No. 25330) when cut Sept. 16, yielded 31 tons per acre of green forage, had no bloom whatever. (See Pl. III, fig. 1.) It and the new varieties now being tested, have been cut twice during the cooler months, the new ratoons heading out again a short time after each cutting. It is possible that dryness during cool weather may influence the bloom somewhat, but it is certain that dryness in hot months exercises no influence. For best yields of seed. however, sorghums should not be cut back in late summer, as was done in the case above mentioned, since with the first rains of the fall, if standing, they grow rapidly and make full crops, but if cut they bloom early with not sufficient growth of plant to fill and mature the seeds.

require the same judicious management as does the pili grass. Teff grass is said to be an annual, but has ratooned freely here during its first trial. From a planting made November 15, 1913, the third cutting of mature grass and seed was made May 27, 1914. The stems are small, the leaves fine, and the entire plant appears to be quite palatable. It seeds freely and will doubtless be able to propagate itself under range conditions much as does kakonakona (*Panicum torridum*).

A number of other grasses were tried out in the grass garden during the year, and although many of them did well, further trial will be necessary in order to determine their value. Mitchell grass (*Astrebla triticoides*), Judd grass (*Leptochloa virgata*), *Paspalum stoloniferum*, molasses grass (*Melinis minutiflora*), *Paspalum virgatum*, *Phalaris bulbosa*, and Texas blue grass are worthy of mention. The American "Buffalo grass" (*Bulbilis dactyloides*) from Kansas seed started very slowly but is making much better growth as the summer months come on. This is one of the best grasses on the Great Plains area of the United States and should be very valuable on the lower dry lands here.

AUSTRALIAN SALTBUSHES.

Several species of Australian saltbushes (*Atriplex* spp.) lately imported into Hawaii are giving satisfactory results as pasture or cover crops for extremely dry and barren localities. Three varieties tested out are the round-leaved saltbush (*A. nummularia*), slender saltbush (*A. leptocarpa*), and gray saltbush (*A. halimoides*). The first-named species has exceptional qualities in its quick, sturdy growth and prolific seeding habits, while the gray and slender saltbushes, though maintaining vigorous growth, are inclined to seed only during the late summer and fall months. However, all have their merits as sturdy, long-period cover crops.

POTATOES.

But few successful potato crops have been harvested in recent years, due to attack from fungus diseases, of which a late blight seems to be the most serious. The stem and root rot, due to *Sclerotinia rolfsii*, which attacks the stem of the vine in its early growth, is generally overcome by deep and thorough cultivation. It has not been determined whether the blight attacking potatoes in Hawaii and the rotting of tubers are caused by the same organism, but on the mainland where potatoes have been killed by blight (*Phytophthora infestans*) resulting tubers were found to be involved in a soft or wet rot, particularly in instances of moist soil conditions. At the station the loss from rotting of tubers has been particularly large when left undug for several days after the killing of the tops by blight.

Difficulties in obtaining full stands have been corrected by entirely discarding the stem end of tubers for seed purposes. Seed treated with formalin by soaking in a solution of 1 pint 40 per cent formalin to 30 gallons of water produced tubers free from scab in every case except when the soil was freshly limed.

Some spraying experiments were conducted during the year. In each instance the spraying was begun when the plants were 6 or 8 inches high, and six to eight applications were given according to the life period of the vines. With White River potatoes no appreciable difference in yields of tubers resulted from rows sprayed with Bordeaux mixture [1] or copper sulphate and washing soda [2] over unsprayed rows, while with Burbank potatoes yields favored the use of Bordeaux mixture. With Irish Cobbler where an 8 : 8 : 60 [3] solution of lime-sulphur spray was applied in the last two applications the yields favored the lime-sulphur over Bordeaux mixture by an 8 per cent increase, the plants maintaining their thrifty appearance two days longer than those sprayed with Bordeaux mixture and twelve days over check rows. When the potatoes are attacked by the potato tuber moth (*Phthorimæa operculella*) or the flea beetle (*Epitrix parvula*) 1 pound of arsenate of lead added to 50 gallons of Bordeaux mixture is recommended.

BUCKWHEAT.

While buckwheat is best adapted to a cool, moist climate, excellent results were obtained from plantings made in early April. Though the blossoming period was attended by excessively hot, dry weather in May, no loss from the blasting of blooms was perceptible. The two varieties under test (Japanese and Silverhull) yielded 25 and 19½ bushels per acre, respectively, in 56 and 63 days. Buckwheat germinates readily and makes good crops in poor soil if well prepared. The ease and quickness of raising this crop recommends its use in regular rotation, particularly as a poultry feed. For best results buckwheat should be sown in drills one foot apart, requiring about one bushel of seed per acre.

FLAX.

Several trial plantings of flax produced good yields of flaxseed, but rather poor yields of straw. Flax requires a light soil well prepared before planting, germinates in 4 days under good conditions, and matures usually in 90 days. It can be drilled or broadcasted, care being taken to insure an even stand when fiber is wanted for manufacture. The average yield of two plantings upon the station grounds was 17 bushels of flaxseed per acre.

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[1] 6 pounds stone lime, 5 pounds copper sulphate, 50 gallons water.

[2] 5 pounds washing soda, 5 pounds copper sulphate, 50 gallons water.

[3] 8 pounds stone lime, 8 pounds sulphur, 60 gallons water.

FIG. 1.—AFRICAN SORGHUM, S. P. I. 25330.

FIG. 2.—SUDAN GRASS ON LEFT, TUNIS GRASS ON RIGHT.

RAPE.

Rape was planted April 5, and grew well at the start. By May 1, when it had gained a height of 10 inches, aphids appeared, and exceedingly hot and dry weather following caused the loss of the entire crop. There seems to be but little doubt that rape will make a good crop when planted at the right season, since it is known that cowpeas, which generally make successful crops, have been killed outright when checked by unseasonable weather conditions together with aphis attack.

LEGUMES.

Of the several legumes introduced during the year German lupine (*Lupinus hartwegii*) gained favor as a green manure crop, yielding at the end of 84 and 96 days, respectively, 9.8 and 18.6 tons green manure and 16.5 bushels of seed per acre. Its habit of growth, while low and spreading at the start, becomes erect and branching as the flower heads appear. Trials with Egyptian clover or berseem (*Trifolium alexandrinum*), Florida beggar weed (*Desmodium tortuosum*), and field burnet (*Sanguisorba minor*) gave fair results, but the field burnet in every trial failed to set blooms and seed. The beggar weed, though known as an annual, has been cut three times, with always a new crop appearing better than the first. Berseem is recommended for higher elevations. The tree lucern (*Cytisus proliferus*), sainfoin (*Onobrychis sativa*), and birdsfoot trefoil (*Lotus corniculatus*) were planted in December, but made little growth until late spring. All but the tree lucern set blooms and pods in May. During early June the sainfoin was attacked by the cottony cushion scale (*Icerya purchasi*), but the plants still held their vigor. In a period of seven months the tree lucern made a growth of 40 inches. The stems are slightly woody, slender, and branching at top.

SUBSTATIONS.

The work at the Kula substation was discontinued at the end of the calendar year 1913. The fall crop of Irish potatoes was a complete failure in spite of spraying. An attempt was made to try out small grains as pasture and green manure crops, the intention being to graze off these crops during the winter months and not to turn them under until time to prepare the land for corn. The crops were turned under, however, after making a good growth in early winter. That these crops will make valuable cover, pasture, and green manure crops at 3,600 feet elevation was fully demonstrated, and it is to be hoped that many in the corn-growing regions will profit by the examples shown them and grow such crops.

At the Waipio substation the agronomy department is interested particularly in a comparison of grain sorghums, Kafir, milo, and

feterita. Heretofore all such crops have failed in this location owing to prolonged drought and unfavorable soil conditions. This season the rains have been more favorable, and better results should be obtained.

SEED DISTRIBUTION.

During the year the demand for seed of field and range crops has become greater than ever before in the history of this department. While the demand for cotton seed has come particularly from the Kona district of Hawaii, seeds of velvet beans, jack beans, lupine, cowpeas, soy beans, peanuts, pigeon peas, corn, broom corn, sorghum, millets, and seeds, roots, and cuttings of lately introduced grasses have been chiefly in demand from homesteading districts throughout the islands.

REPORT OF THE ENTOMOLOGIST.

By D. T. Fullaway.

Little entomological work was done at the station during the year, on account of the absence of the entomologist. From July 1 to October 15 he was on detail with the Territorial Board of Agriculture and Forestry. An account of the work performed under its auspices is contained in a recent bulletin published by that organization.[1] From October 15 to February 28 he was on leave of absence engaged in entomological work for the Philippine government. He was away again from June 1 under the auspices of the Territory. The routine work of the office, however, has been adequately attended to and the insect collection maintained and increased by numerous additions, especially an extensive collection of Philippine insects.

Some further work has been done on the insect pests of vegetables, and there follows an account of the insects found in connection with the cultivation of cabbage, turnip, radish, lettuce, etc. Most of these are common and well-known vegetable pests on the mainland and in Europe, which have undoubtedly been introduced into Hawaii in shipments of fresh vegetables. Because of the great losses they have caused in truck farming they have naturally been the subject of many reports and bulletins elsewhere, and in Hawaii they have been dealt with in the reports of Koebele to the Hawaiian minister of the interior, in the annual reports of this station, and at some length in a report by Marsh.[2] Hardly any new or original matter, therefore, appears in this account, but in view of the economic importance of vegetable crops in connection with a growing population, which will provide a constant and ready market for all that can be produced, it is believed that the information here presented in regard to some of the drawbacks and how in part they may be overcome is desirable and will be useful to growers.

The three principal pests of crucifers in Hawaii are the imported cabbage worm (*Pontia rapæ*), the cabbage webworm (*Hellula undalis*), and the diamond-backed cabbage moth (*Plutella maculipennis*). The cabbage aphis (*Aphis brassicæ* and *Myzus persicæ*) are also bad at times. The serpentine leaf miner, cutworms, and other caterpillars of general feeding habits, as well as grasshoppers and thrips, are pests of minor importance.

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[1] Bd. Comrs. Agr. and Forestry Hawaii, Div. Ent., Bul. 3 (1914), p. 148.

[2] Marsh, H. O. [Bien.] Rpt. Bd. Comrs. Agr. and Forestry Hawaii, 1909–10, pp. 152–159.

THE IMPORTED CABBAGE WORM.

The imported cabbage worm is probably as well known as any of the insects which enter into man's domestic economy, and few fail to connect the velvety green caterpillar which feeds so freely on the plants with the large white butterfly which flits restlessly up and down the cabbage or turnip patch. The freedom with which this insect works, in fact, leaves no excuse for ignorance on this point, for often under one's very eyes the butterfly will stop and deposit on a leaf the egg from which the caterpillar later on hatches. It is one of the commonest insects, and it is rare that a cabbage plant can be grown to maturity without being attacked by it. With cabbage grown under field conditions, it becomes an absolute scourge, requiring all the ingenuity, patience, and thoroughness one can possibly develop to cope with it, and as cabbage is the only cruciferous crop cultivated under field conditions in Hawaii, the damage from this insect yearly is very large.

The insect is a well-known European species which became established in eastern Canada, presumably by introduction with vegetables about 1856. Since then it has gradually spread westward and southward in Canada and the United States, reaching Chicago in 1877, the Gulf coast in 1880, and the Pacific slope in 1883. It was first noticed in Hawaii in 1898 and is reported by Koebele[1] to have been introduced with shipments of cabbages from the coast.

The caterpillars are usually found in rather exposed positions on the leaves, which they eat through or gnaw from the edges, giving the outer ones a very ragged appearance. In cabbage which is just heading they often "worm" from leaf to leaf through the head and leave considerable frass behind, which is likely to set up fermentation and spoil the whole plant for any use. Manifestly, the time to deal with these worms is when they are young to half grown, and if the plants can be started in frames under partial cover, so that the butterfly is unable to reach them to deposit its eggs, it is possible to get them well along toward heading with little or no infestation.

The eggs are laid singly on the leaves, usually on the underside, though this is by no means always the case. They are fusiform in shape, placed on end, but with a moderately wide and firm base, are yellow and radiately ribbed, about $\frac{1}{25}$ inch high and readily seen with the naked eye. They hatch at the end of 4 days.

The larva or worm when it hatches from the egg is very small (about $\frac{1}{15}$ inch long). It increases in size rapidly, however, and at the end of 14 days is full grown and ready to pupate. At this time it is an inch or more in length and a velvety green with a yellowish

[1] Rpt. Min. Int. Hawaii, 1898, p. 87.

stripe down the middle of the back and a line of yellow spots on either side near the breathing pores.

The worm often leaves the plant to pupate in the shelter of some convenient object, but the pupa is also sometimes found fastened by a silken girdle to a leaf of the plant. It is about $\frac{3}{4}$ inch long, angular and ridged, in places somewhat spiny, green to gray, flecked with black; the frontal projection is rather long and sharp with two stout spines behind; at the tip are many closely crowded recurved hairs or spines. The pupal stage is from 8 to 12 days.

The adult butterfly has a wing expanse of 2 inches, is yellowish white, marked with black near the tips of the forewings and a black spot on the disk (two in the female); also a similar spot on the costal margin of the hind wing. It has a slow and lumbering flight, but is extremely active, especially on bright days. One female was observed to lay more than 20 eggs in less than an hour without exhausting herself.

Arsenic sprays are recommended to reduce this pest (arsenate of lead or Paris green and lime). Boiling water is also considered good. The spray must be applied to the underside of the leaves as well as the upper; the spraying outfit therefore should be provided with an extension rod.

The tachinid fly, *Frontina archippivora,* is very commonly bred from these worms and it undoubtedly does much to check their multiplication. *Chalcis obscurata* has also been bred from the pupa, and a bacterial disease is quite common among the worms.

THE IMPORTED CABBAGE WEBWORM.

The imported cabbage webworm, although much more obscure in its operations than the common cabbage worm, is nearly if not fully as destructive. It is equally prolific and just as injurious to cabbage and related crops. In fact, it is more to be dreaded than the other species on account of its peculiar habit of attacking particularly the bud, and because of its ability to escape the action of insecticides in the protection of its web. The pest is found in the Mediterranean region and generally throughout the tropical portions of the Old World. It was apparently of early introduction into Hawaii, as examples were taken by Perkins (1892–1895). It was not generally recognized as a pest in the States until 1897.

The eggs are usually laid about the bud, in the axils of the terminal leaves, oftentimes also on the upper surface of the leaves in the hollows formed by the leaf veins. They are extremely small (about $\frac{1}{50}$ inch), oval, not particularly flat, and are yellowish white flecked with reddish spots and microscopically sculptured. They hatch in from 3 to 5 days.

After hatching from the egg the young larva begins to feed on the leaves, especially the young tender leaves of the bud, and usually spins a web about itself between two leaf surfaces. Often it mines into the stalk or midrib of the leaf. The result of its work quite frequently is the complete destruction of seedling plants. Larger plants are either stunted or deformed, so that they can not make a normal growth. The worm is full grown in about 18 days, and at this stage is about ½ inch long, fairly stout and hairy, with head black and body yellowish brown marked with a thin dark-brown stripe down the center of the back and two similar stripes on the sides, the inner of which is wider than the outer.

The worm pupates in the ground in a rather loose cocoon made of particles of soil webbed together with finely spun silk. The pupa is a quite ordinary kind about ⅓ inch long, shining light brown with dark stripe on back, and a bunch of four fairly long recurved hairs at the tip. The pupal stage lasts from 10 to 15 days.

The adult moth has a wing expanse of ¾ inch, is generally gray, the forewings with darker areas about two wavy white lines which cross the disk at about one-third and two-thirds its length. They fly readily, but are more or less obscure in their habits, and are not often seen in the cabbage fields.

H. O. Marsh experimented on the control of this pest with different insecticidal mixtures, but found nothing that could be depended upon, and recommended screening the seed beds and clean culture as the only means of lessening its depredations.[1] He recommends cotton mosquito netting, but the writer has found wire netting more suitable, and the plants should be 5 to 6 inches high and have a vigorous growth before being set out. The braconid, *Chelonus blackburni*, is a very common parasite of this species.

THE DIAMOND-BACKED CABBAGE MOTH.

The diamond-backed cabbage moth takes its popular name from the peculiar diamond-like pattern of the coloration of the moth; the damage to the crop (cabbage, turnip, etc.), is done entirely by the worm, which is now almost cosmopolitan. It probably originated on the Continent, where it first came to notice as a vegetable pest. In the early fifties it was discovered in the United States; later it was found in Australia, New Zealand, South America, and in Africa, at the Cape. According to Koebele, it was an early introduction into Hawaii.

The damage to the plants caused by this pest results from the destruction of the leaves, which the worms, when present in force, quickly riddle with holes. As the species is extremely prolific, the plants are soon shattered, unless in some way protected.

[1] Chittenden, F. H., and Marsh, H. D. U. S. Dept. Agr., Bur. Ent. Bul. 109, pt. 3 (1912).

The eggs are deposited singly in large numbers on the leaves, usually in the hollow alongside a leaf-vein. They are extremely small ($\frac{1}{40}$ inch), flat, oval, lemon yellow, with iridescent, roughened surface, and hatch in 4 days.

The larva, when hatched from the egg, is very small, but increases in size gradually with age. At the end of 10 days it is full grown and ready to spin its web and pupate. At this time it is a remarkably active slender green worm, nearly $\frac{1}{3}$ inch long, somewhat constricted along the body, which bears microscopic dark spots and hairs. If suddenly disturbed it is most likely to wriggle away with some very lively contortions and drop from the leaf, suspending itself by a silken thread. It is at this period of its cycle that the insect is destructive and also most susceptible to attack with poisons, washes, etc., but its concealed position on the unexposed portions of the foliage must be taken into consideration.

The pupa, as already intimated, is partially concealed and protected by a rather unique, loosely woven, wide-meshed web, attached on all sides to the surface of the leaf. It is a little less than $\frac{1}{4}$ inch long, slender, greenish yellow to pale brown, with a few small tubercles on the head and a bunch of spiny hairs at the tip. Within it the moth develops in from 6 to 8 days and emerges by bursting through the anterior end of the case and its web.

The moth is about $\frac{1}{3}$ inch long with the wings closed and measures $\frac{1}{2}$ inch across when these are spread out. It is generally an ashy gray. The forewings, however, are flecked with black on the disc and apex and have a wide black streak extending from the base through the middle for about half their length. Between this area of black and the hind margin the wing is creamy white, the line of separation usually somewhat wavy. The hind wings are a glossy leaden gray, the antennæ and underside of the body almost white.

Sprays are recommended to reduce the damage of this destructive worm in cabbage and turnip fields, and the remedies commonly used for the other cabbage worms (arsenic, kerosene emulsion, and hot water) are effective for this pest as well. The multiplication of the insect is also greatly checked by the hymenopterous parasites, *Limnerium blackburni*.

These three species, which have been especially mentioned, are all, with regard to their food plants, confined entirely to crucifers, although my observation from the beginning has been that the injurious effects in the case of each species are more noticeable in some crops than in others. Thus the cabbage worm (white cabbage butterfly) does more damage to cabbage than to other crops, although turnips and cauliflower are also attacked. The worm of the diamond-backed moth is most injurious to thin-leaved plants and seedlings; on the tough rubbery leaves of cabbage it has hardly any

effect. The webworm does greater damage to root crops—radishes and turnips—on account of its habit of eating out the bud. It also destroys the foliage of thin-leaved plants.

OTHER PESTS OF CRUCIFERÆ.

The best known aphid in connection with crucifers is the common cabbage louse, *Aphis brassicæ*, but in Hawaii this species is much less numerous than another, *Myzus persicæ*, which on the mainland and in Europe is found principally in connection with the peach. The two species are entirely dissimilar, the latter being a naked green louse, while the former is always covered with a whitish mealy coat. The injury inflicted by aphids results from the withdrawal of the cell sap of plants, causing the rapid withering of the leaves, which may be a mere temporary disturbance or fatal, depending on the extent of the infestation. Both species here are effectively controlled by a hymenopterous parasite (*Diæretus rapæ*) and the dry tumid bodies of parasitized individuals are a common sight on the outer leaves of any crucifer. Aphids, therefore, would be considered a negligible factor in the cultivation of cabbage and related crops were it not for the fact that peculiar weather conditions in Hawaii sometimes favor the rapid multiplication of these pests and occasionally seed-bed plants become badly infested with *Myzus persicæ* so that the plants are greatly retarded or killed outright. These infestations may be promptly remedied by spraying the plants with whale-oil soap (1 pound to 5 gallons of water), blackleaf 40 (1 fluid ounce with 3 ounces of whale-oil soap and 4 gallons of water), or miscible oils (directions for the application of which usually accompany the containers).

The serpentine leaf miner is extremely conspicuous in vegetable gardens where thin-leafed crucifers, such as turnips, daikon, shirona, etc., are growing, but is of no great importance as a crop pest on account of the trivial nature of its injuries and its heavy parasitization. It has recently been studied in the United States by the entomologists of the Department of Agriculture, who found that the same insect previously known under several different names attacks a wide variety of plants. It does the same here, and has been found in geranium, nasturtium, and beets in addition to many cruciferous and leguminous crop plants. The insect is a common European pest which has spread eastward into Egypt and westward upon the American Continent. The damage it causes, as already indicated, is slight and comes from the injury to the foliage caused by the mines of the larvæ or maggots. The eggs are laid deep in the mesophyll of the leaf, are white, oval, and almost microscopic in size ($\frac{1}{100}$ inch). They hatch in 4 days. The larva begins its mine from the position of the egg and its progress is indicated by a bleached wandering track

which enlarges with the growth of the maggot and may end in a pocket. The larva is a slender, shining, yellowish maggot about one-eighth inch long when full grown, with spiracular protuberances and black oral appendages which are almost constantly in motion, rasping away the mesophyl. It continues feeding and advancing in the leaf until it is ready to pupate, usually for 9 or 10 days; then it leaves the leaf end and enters the soil. The pupa is inclosed in an oblong, oval puparium about one-twelfth inch long, distinctly segmented, brown, and with prominent spiracular openings in front and behind. The insect remains in the pupal stage for 6 days, at the end of which the perfect insect emerges. This is a small black and yellow two-winged fly so commonly seen hovering about the cabbage patch. The cycle of the fly in Hawaii according to the above data, which were obtained in April, requires from 20 to 25 days. There would probably be some acceleration of the development in the summer and a slight retardation in the winter months.

Three hymenopterous parasites have been bred from the species belonging to the genera Derostenus, Diaulinus, and Chrysocharis. These are usually active enough to keep the pest well checked and no remedial measures are suggested or considered necessary.

Several species of thrips are also commonly found on crucifers but can not be considered of much importance from the growers' standpoint. The commonest is the onion thrips (*Thrips tabaci*), a pale species. Less common is a dark species of Chirothrips.

Cutworms are also occasionally found and are the common garden species which have been repeatedly reported as attacking succulent plants indiscriminately (*Agrotis ypsilon*, *A. crinigera*, and *Caradrina exigua*). A few other leaf-feeding caterpillars have also at times been encountered. *Hymeria fascialis*, *Plusia chalcites*, and the long-horned grasshopper (*Atractomorpha crenaticeps*). All these are adequately controlled by parasites and are not particularly injurious, but if so at all, their prevalence is in the nature of an outbreak which can scarcely be foreseen, is easily checked by arsenic sprays, and at all events is not likely to be of long duration. The melon fly (*Dacus cucurbitæ*) has often been reported infesting the heart of cabbage, but the infestation is not at all common and is considered to be due to abnormal conditions in the plant, and of a secondary nature.

One of the principal sources of trouble in growing cruciferous crops is the absence of clean cultivation. Specific measures of control have been advised in the case of each of the pests above discussed, but these measures relate to infestations which already prevail. Unfortunately, also, they entail considerable labor and expense and are often partly or entirely ineffective. In many cases, moreover, the conditions would be very different if clean cultivation

had been constantly practiced. This applies particularly to the control of the more insidious pests and to districts where cruciferous crops are raised continuously from year to year. In such places the production of cruciferous crops with profit after a time becomes almost an impossibility owing to the cumulative factor in the natural increase of the pest concerned. It is therefore desirable that when the crops are taken off the stumps be pulled and these together with discarded leaves and all other trash in the fields be disposed of so that the insects in them are unable to breed out. This might be accomplished by deep plowing, though the results would undoubtedly be better if the trash were burned or buried several feet below the surface of the ground. This measure is almost essential in dealing with hardy insects in a country where breeding goes on throughout the entire year, and would take the place and bring about the beneficial results in the way of insect destruction attending the long seasons of low temperature in more northern latitudes.

REPORT OF THE SUPERINTENDENT OF THE RUBBER SUBSTATION.

By W. A. Anderson.

The most important developments at the rubber substation were in connection with observations on the latex-bearing qualities of individual trees, the possibility of propagating for these properties, and the suitability of roselle as an intercrop for rubber..

PLANTING CUTTINGS.

The wide variation in the yields of individuals among Ceara (*Manihot glaziovii*) rubber trees, suggests the possibility of developing a plantation by propagating from exceptionally good yielders with a view to eliminating this wide variation, and obtaining a stand on which all the trees will be large yielders. Seedlings can not be depended upon to come true, and, consequently, in 1912, an experiment was planned to determine the feasibility of transmitting high yielding properties through cuttings.

In February, 1912, 200 cuttings of various size were taken from trees that were considered good yielders, and planted on land belonging to The Hawaiian American Rubber Co., in Nahiku. During 1912 broom corn was planted among these trees, and in 1913, roselle, so that they have been fairly well cultivated during the two years. In January, 1914, when the trees were 1 year and 11 months old, they were tapped with a single cut. The new growth on these trees, 1 foot above the original cutting, averaged 10.8 inches in circumference. They yielded 16 ounces washed rubber from one tapping, of one cut per tree. This is equal, in both yield per tree and returns for labor, to the average reported from 6-year old trees unselected, tapped in 1912. The yield from the different trees was more uniform than on the plantations as a whole, and the results indicate that this method of propagation can be successfully employed to transmit desirable latex-yielding properties.

It was also observed, in tapping experiments on 7-year old trees in the fall of 1913, that the best trees yielded as high as 2 ounces wet rubber at one tapping equivalent to about 1.36 ounces dry rubber. By the method employed in obtaining this yield, one man averaged 200 trees, tapping and collecting, per day's work. The number of

these high yielding trees is small, averaging probably not more than one or two per acre over all the plantations. If all the trees yielded in this manner, rubber could be collected at the rate of 17 pounds dry rubber per man a day. At $1 per day, the average wage for tapping, the rubber would cost about 6 cents per pound for tapping alone. Factory expense, packing and shipping, freights, insurance, and commissions should not exceed 15 cents per pound, and in large quantities could be made much less than this. Other overhead charges would depend on the amount of rubber produced, and can be estimated only on the basis of the number of trees tapped and the yield per tree per year. However, at these figures, there would seem to be a fair margin of profit, even at the present price of rubber.

This high yield of the best trees, coupled with the indication that the high-yielding properties can be transmitted through cuttings, suggests a method by which Hawaiian rubber can be produced at a profit even with low prices for the product. By discarding all unprofitable trees, and planting cuttings from these few best trees, plantations can be developed from which rubber can be obtained at a low tapping cost. This experiment at its present stage, indicates only that the trees obtained from cuttings in this way will give more uniform and larger yields than can be obtained from the ordinary methods of planting with seedlings. Whether trees raised from cuttings taken from trees yielding 2 ounces per tapping, will likewise yield 2 ounces per tapping, can be determined only by keeping a record of the trees from which the individual cuttings were made, and comparing the yield from the resulting trees when they shall have reached the age of the parents at the time the cuttings were taken. As the trees from which 2 ounces per tapping was obtained were seven years old, it would take seven years to determine this point definitely. However, since the yield from these 2-year old cuttings equalled the average yield from ordinary 6-year old trees, it would seem reasonable to assume that it was approximately as large as that of the present trees at two years of age. It will be interesting at least to watch these young trees and to note their performance at maturity.

ROSELLE.

Roselle (*Hibiscus sabdariffa*) was planted on a commercial scale between the rubber trees on two of the plantations during 1913. Results indicated that, with a market for the fresh fruit at 3 to 4 cents a pound, this would be a profitable intercrop. At present, however, there is practically no market for the fresh fruit while a limited market does exist for the dried fruit at 30 to 40 cents per pound, which is equivalent to $2\frac{1}{2}$ to $3\frac{1}{3}$ cents per pound for the fresh fruit less the cost of drying.

Even at this price, however, the results of last year's experiment were so promising that five farmers besides two of the rubber plantations are planting this year, with a total area of about 220 acres.

The rubber trees among which the roselle was planted were spaced 10 by 20 feet. The roselle was accordingly planted 5 by 5 feet as the most convenient spacing to utilize the soil in conjunction with the trees. This is rather close planting where the bushes grow as large as in the Nahiku district. In the early plantings on the lower elevations, the plants grew to a height of 8 to 10 feet, bearing the fruit rather too high for convenient picking. These plants yielded, however, at the rate of 10 pounds of fruit per plant, or roughly, 15,000 pounds per acre among the rubber trees. With the same yield per plant, and the rubber trees replaced by roselle plants, we should have had over 17,000 pounds per acre, which is a larger yield than has been elsewhere reported.

During the same year a planting of 25 acres was made in the Kona district of Hawaii, under the supervision of Mr. R. V. Woods, of the Kona Kanning Ko., who reported the results as indicating that, while planted as a catch crop among other things it might prove profitable, it was not profitable as a crop by itself. The failure in Kona was no doubt partially due to the unusually dry season during the period of growth, while the copious rainfall in Nahiku may be partially responsible for the highly satisfactory yield in this district. During the eight months from the time the first seed was planted to the time of harvesting, the precipitation amounted to 109.17 inches. The partial protection from the trade winds afforded by the rubber trees among which they were planted may also have helped to increase the yield. Whatever the causes, the results would indicate that the Nahiku district is well suited to the growing of this fruit among rubber trees.

Considerable difficulty was experienced in drying the fruit. It was at first thought that the drying could be done at ordinary temperature in a drying house built according to the plan given for a tobacco drying house.[1] Harvesting began in November, and during this month 26 inches of rain fell. It was found the fruit would not dry without artificial heat. Consequently, the drying house was equipped with steam heat. While the building was poorly adapted to this method it was found that, at a temperature of 120 to 140° the fruit would dry bone dry in 24 to 48 hours. The proportion of fresh fruit to dried was roughly the same as previously reported from the experiment station grounds in Honolulu.[2]

Picking is the most expensive operation in connection with the handling of the crop. At first the fruit was picked and carried com-

[1] Hawaii Sta. Bul. 15.

[2] Hawaii Sta. Rpt. 1909, p. 55.

plete to the drying house, where it was seeded into the drying trays. It was found cheaper, however, to remove the seed pod in the field at the time of picking. This avoids one handling of the entire weight of the fruit, and saves about one-third in the weight that must be transported to the drying house. At the same time, it avoids another handling of the seed pods, which must be removed from the drying house after seeding by the first method, and leaves the green seeds and pods on the field for whatever fertilizing value they may have. With the price of labor averaging $1 per day, it cost 2 cents per pound of seeded fruit to harvest the crop in this way. The saving in handling and transportation was the chief advantage of the second method.

Considerable loss was experienced from cutworms, both in the nurseries and after transplanting. This has been largely avoided this year by protecting the nurseries with ditches, planting as much as possible between the cutworm seasons, and allowing the plants to remain longer in the nurseries before transplanting. Not only the planting in nurseries, but the transplanting should be done between the cutworm seasons as far as possible. If not planted too thickly in the nurseries, the seedlings can be allowed to reach a height of 1½ to 2 feet before transplanting, without serious injury. This has a tendency, however, to make them branch high, and a better size for transplanting is 6 inches to 1 foot. With the seedlings ready in the nurseries, a few can be transplanted and watched a few days for evidences of cutworms. When it is found that the cutworms do not attack these, the transplanting can be done with comparative safety. Losses from this source this year have been negligible.

The work on this crop has shown:

(1) That large yields can be obtained in this locality when planted between rubber trees;

(2) That some means must be provided for drying artificially;

(3) That unless precautions are taken cutworms will cause serious losses, but that this loss can be largely avoided; and

(4) That if the work is all done by hand with tools now available, the crop can be most economically handled by picking and seeding at one operation in the field.

The value of the crop planted this year by five farmers and two rubber companies is conservatively valued at $52,800.

There is some indication that certain of the plants, by proper handling and judicious pruning, can be made to grow and bear a second year. This would seem to be a proper subject for further investigations.

EFFECT OF FERTILIZERS ON THE YIELD OF RUBBER.

The object of this experiment was to determine the advantage, if any, in the use of the ordinary fertilizers to increase the yield of rubber during a tapping season. A block of 1,000 trees was divided into 10 plats, numbered 1 to 10. The odd sections were left unfertilized for check, and the even sections fertilized with equal amounts of phosphoric acid in the form of superphosphate, potash in the form of potassium sulphate, and nitrogen in the forms of sodium nitrate and ammonium sulphate. The trees were measured at the beginning and at the end of the experiment. The sodium nitrate was divided into four applications, but rainy weather destroyed the results of the tapping after the last application, so that the results are tabulated for only three series of tappings with three-fourths of the nitrate.

Ten tappings were made during September, October, and November, and five during February. Sodium nitrate was applied just before each of the tappings. In the three series of tappings, results per tree were as follows:

Effect of fertilizers on yield of rubber.

Plat No.	Fertilizer.	Yield.
		Ounces.
1	No fertilizer	1.54
2	Superphosphate, 375 pounds, and potassium sulphate, 125 pounds	1.57
3	No fertilizer	1.1
4	Superphosphate, 375 pounds; potassium sulphate, 125 pounds; and ammonium sulphate, 375 pounds	1.4
5	No fertilizer	1.32
6	Superphosphate 375 pounds, potassium sulphate 125 pounds, and sodium nitrate 375 pounds	1.4
7	No fertilizer	1.43
8	Ammonium sulphate 375 pounds	1.55
9	No fertilizer	1.44
10	Sodium nitrate 375 pounds	1.48

Comparing the yield per tree from each of the fertilized plats with the average from the two unfertilized plats on either side, plat 2 exceeded plats 1 and 3 by 19 per cent, plat 4 exceeded 3 and 5 by 15 per cent, plat 6 exceeded plats 5 and 7 by 5 per cent, plat 8 exceeded plats 7 and 9 by $8\frac{1}{2}$ per cent, and plat 10 exceeded plat 9 by 3 per cent. Had all the scrap been collected, the nitrate fertilized plats would have made a better comparative showing. The trees on these two plats retained more rubber after each tapping that had coagulated on the trees. This was more noticeable in the case of plat 10, fertilized with nitrate alone.

Following are the girths of the trees in inches, at the beginning and at the end of the experiment:

Effect of fertilizers on circumference growth of rubber trees.

Plat No.	Fertilizer.	At beginning of experiment.	At end of experiment.
		Inches.	*Inches.*
1	No fertilizer	16	17.9
2	Superphosphate 375 pounds, potassium sulphate 125 pounds	15.97	18.5
3	No fertilizer	15.75	19.6
4	Superphosphate 375 pounds, potassium sulphate 125 pounds, and ammonium sulphate 375 pounds	17.23	19.2
5	No fertilizer	16.9	19
6	Superphosphate 375 pounds, potassium sulphate 125 pounds, and sodium nitrate 375 pounds	16.34	18.4
7	No fertilizer	15.55	18.4
8	Ammonium sulphate 375 pounds	14.78	16.5
9	No fertilizer	16.5	18.1
10	Sodium nitrate 375 pounds	15.2	17.7

With the exception of plat 3, the largest increase in girth is in the section fertilized with superphosphate and potassium sulphate. Why it should be greater in this case than in that of the trees fertilized with these fertilizers plus ammonium sulphate or sodium nitrate is hard to say, but the same was noted in measurements of trees on which an experiment was made in 1909 and 1910.

In general, the results show an increased yield resulting from the use of fertilizers. The increase varies from 3 per cent, in the case of nitrate alone, to 19 per cent, in the case of superphosphate and potassium sulphate.

Superphosphate and potassium sulphate, in combination with ammonium sulphate, show a greater increase than the same two in combination with sodium nitrate. Superphosphate, potassium sulphate, and sodium nitrate show an increase of 19 ounces between the first and third tappings. The largest yield per tree was obtained from superphosphate and potassium sulphate. The next largest from ammonium sulphate alone, though this was only 0.07 ounce greater than that obtained from three-fourths as much sodium nitrate. The difference in cost of material and application would perhaps be the determining factor in deciding between these two. The largest difference between the yield of fertilized and adjacent unfertilized trees was also obtained in the case of potassium sulphate and superphosphate.

REPORT OF THE SUPERINTENDENT OF THE HAWAII SUBSTATIONS.

By F. A. Clowes.

HILO SUBSTATION.

BANANAS.

During the year the experimental plat for studying the influence of planting bananas at various distances apart, as described in the annual report of this station for 1912, was replanted. In replanting, a plat was added in which the bananas were 6 by 6 feet apart. This plat will be harvested in the latter part of 1914.

TARO.

A quarter of an acre was planted in taro in February to determine the relative value of three classes of seed, or hulo, namely the parent or makua, the oha or seed from large tubers, and the piu, or small tubers. This area had been planted in 1911, and harvested in 1912. It is intended to replant it at least three times before attempting to draw conclusions. In the 1911 experiment, just one variety, the Kuoho was used. In the 1913 experiment the following varieties were used: Kuoho, Eleele, Lehua, Makaua, Papa pulo, and Nana (Ulaipio). The experiment will be a test of some of the standard varieties, as well as a "seed"-selection test. The crop will be harvested in the latter part of 1914.

SCHOOL GARDENS.

The classes in agriculture of the Hilo Union School were given the use of the interspaces between the freshly-planted bananas for six months. Gardening was done on this land under the direction of E. G. Allen, of the Hilo High School. A study of the work done by these classes suggests ideas which promise to be of value in developing the possibilities of teaching agriculture. A half acre of the substation has been set aside for the use of the classes next year and an effort will be made to develop farther the possibilities of teaching agriculture through school gardens.

GLENWOOD SUBSTATION.

In Olaa comparatively few days go by without rainfall. In upper Olaa it is not uncommon for a month to pass with but a half dozen glimpses of the sun. From April 1 till June 30, 1914, eight acres intended for spring planting at the substation lay fallow waiting for suitable weather to render it dry enough to harrow. This is not at all an uncommon occurrence in Olaa as elsewhere on the windward sides of the larger islands, at elevations above fifteen hundred feet. Nevertheless, periods of several weeks will elapse when sunny skies and slight precipitation prevail. There is, however, no definite dry or wet season and all empirical rules regarding the weather probabilities are very uncertain. The conditions are so different from European and American conditions, that there is little recorded experience available to aid in developing a system of agriculture suited to this region.

Farmers in Olaa are adopting a system of agriculture apparently suited to the climate. The popularity of soiling crops such as honohono (*Commelina nudiflora*) and Para grass can be accounted for by the fact that they are perennial and require little cultivation other than top-dressing with manure. Their use is becoming general where any attempt at all is made to supplement the natural pastures by green crops. It is probable that an extension of the present crude system of live-stock farming with honohono and Para grass as the main crops, could be made very profitable. In the summer months there is much more growth than during the winter. Honohono lodges badly and Para grass becomes woody if left in the field after a certain stage of development. To prevent loss of the surplus in summer, some means of storing is needed. The silo offers one means of solving this difficulty. A hay-drying kiln, either under cooperative or individual ownership, would offer an additional means of storing feed, and would also make Para grass hay a possibility. Since practically all the hay used in the Territory is imported it would seem that a ready market is at hand for a great deal of hay which could thus be a by-product of the live-stock farms of this region. The care of manure is a problem that requires study. There is little available litter to be used as an absorbent. It is consequently difficult both to keep cattle clean in the stable and to absorb the liquid manure to make it convenient to handle. Some dairymen are saving the liquid which is voided while the stock are in the stable by running it into barrels and then carrying it out in buckets. While this means is effective it needs modification in the interests of economy of labor. The matter of economical methods of handling this valuable by-product of the live-stock industry merits attention, since the difference between profit and loss in manufacturing and

agricultural industries largely depends upon the advantageous utilization of the by-products.

An island-bred mare of good medium heavy type was purchased in July. The prime object in buying her was to secure a work animal. She has been bred to a large standard-bred stallion.

CATTLE.

During the year the station herd of cattle was increased by the birth of two bull and two heifer calves, all pure-bred Guernseys, eligible to registry. The herd bull, Raymond of Alta Vista, has stood for service throughout the year. All the farmers within reach have taken advantage of this opportunity. A census of the calves in the neighborhood shows that there are 15 grade heifers sired by the substation bull, distributed among 9 different owners.

POULTRY.

In January a small flock of Rhode Island Red chickens was purchased. White Leghorn eggs were also purchased and hatched in an incubator and the chickens reared indoors in deep litter brooders. It is intended to increase the flock of poultry this year, to study problems connected therewith, and by trap-nesting to develop a high egg laying strain in order to supply farmers with more productive laying stock. A small flock of White Muscovy and another flock of Indian Runner ducks has also been purchased.

CREAMERY.

It had been hoped that the cooperation of all the dairymen within reach could be secured for the Glenwood Creamery Co., which was organized with the assistance of the substation. This cooperation was not secured. Sufficient interest had not been developed among the patrons in delivering sweet cream and the grades established proved to be too low. During the warm months of summer the butter lacked keeping quality and the best prices were not secured. It was proved, however, that sweet cream could be delivered without the use of ice by attention to cleanliness and promptly cooling cream to air temperatures. The output of the creamery was only half of what has been hoped for. This made the cost of manufacture double what was expected. It became apparent, therefore, that it was not advisable to continue operating the creamery as a cooperative enterprise. The company therefore resolved itself into a cooperative marketing association in December. To date it has been doing satisfactory work as a cooperative marketing and buying association, and the field of its operations is extending. Ultimately, it may establish a creamery when circumstances justify it. The substation

has rendered it special assistance, because it is a pioneer organization of its kind so far as Hawaii is concerned. It is now so well established that the assistance of the substation is no longer required.

The substation has bought cream from a few neighboring farmers and is making butter to study problems which arise in connection therewith. The butter made is marketed through the creamery company.

CORN AND SORGHUM.

Three acres of corn of the native white variety from Waimea were grown for the silo. A representative row in this field was weighed and produced at the rate of 8.5 tons per acre. Two acres of Early Orange sorghum were grown for the silo. A representative plat of the field was weighed and produced at the rate of 12.5 tons per acre. Part of the sorghum field was allowed to ratoon, and was used for green fodder as required.

GRASSES.

Para grass maintains its lead as the most promising grass for pasture or soiling purposes.

Giant water grass, Natal grass, Italian rye grass, orchard grass, and redtop have all done well and would probably be valuable as pasture grasses.

The area of honohono for soiling purposes has been increased as rapidly as the supply of stable manure permitted. There is now about a half acre which is being cut for stable feeding, daily, and top-dressed with manure after each cutting. Records of the yield are being kept in order to make comparisons with Para and other grasses.

LEGUMES.

Soy beans were sown broadcast on the corn stubble in November. A very poor stand was secured, which was plowed under in January and the ground planted to wheat and kidney beans. These produced a light growth, which was plowed under in March, as green manure. No satisfactory results were secured from any legumes.

EXTENSION WORK.

During the year assistance was rendered in the organization of two associations of cane planters. One was the East Hawaii Cane Planters' Association, an organization of English speaking cane planters, and those interested in sugar cane. The purpose of the organization was to assist in matters of interest mutual to the members of the association. It is intended to work along the lines adopted by farmers' clubs elsewhere.

A federation of associations similar to the above was also formed. This federation adopted the name of "Hilo-Puna Cane Planters' Union." It aims to federate all associations of cane planters, regardless of language and locality. The unit organization paid into the union assessments at the rate of 30 cents per year for each acre cultivated or controlled by the individual members of the associations. The fund thus raised is being used to secure expert assistance from legal and chemical advisers in connection with difficulties that arise in regard to the marketing of sugar cane. The charter members of the union are the Hakalau Sugar Planters' Association, the Wainaku Sugar Planters' Association, the Honomu Sugar Planters' Association, and the East Hawaii Cane Planters' Association. The union is accomplishing much good by overcoming causes of friction between cane planters and mill managers.

During the year six talks were given to the classes in agriculture at the Hilo Boarding School and the Hilo High School.

SILO.

In September a concrete pit silo was built, 12 feet in diameter, and 12½ feet in depth. The bottom is 4 feet below the level of the stable and the top level with the top of the bank at the rear of the stable. This was filled twice, in October and February. A 7-inch hand-power feed cutter, equipped with a pulley and driven by a 1½ horsepower gasoline engine, was used to cut up the fodder. The feed cutter was placed on timbers across the top of the silo so that the cut fodder fell from the machine directly into the silo.

In October the silo was filled with corn, sorghum, and Para grass; in February it was filled with sugar cane, sorghum, and Para grass. Special interest is attached to the ensiling of sugar cane and Para grass, as the use of these two crops in the silo is comparatively new. Sugar cane made excellent silage, very sweet, little more acid than corn silage, with very agreeable odor, and was readily eaten by the stock. Para grass, mixed with a little honohono, also made silage which the stock ate readily, though of a less agreeable odor than other standard silage crops. Both of these crops are big yielders and are promising for cattle feed.

In June a 20-foot redwood silo was placed on top of the concrete silo already in use. This made a silo 32½ feet deep by 12 feet in diameter. This was filled with cane tops in June in cooperation with the Olaa Sugar Co.

THE COMPOSITION OF HAWAIIAN FRUITS AND NUTS.

By Alice R. Thompson, *Assistant Chemist.*

INTRODUCTION.

The analyses on which this report is based were made to gain information upon the chemical composition of the common fruits and nuts which occur in the Territory. The station receives frequent requests for information regarding the composition of ripe fruits of various kinds and regarding the changes in composition which take place during ripening. Almost every fruit consumer has preconceived notions or desires to know more about the nature of his favorite fruits, their nutritive value and possible physiological effects.

Many of the fruits studied by the station have been previously analyzed, but few of these analyses are based on Hawaiian specimens. Moreover, the analyses were made in various parts of the world, in many cases, from fruits which had been shipped long distances in cold storage. The results thus obtained are not strictly comparable, one with another, for the reason that they were obtained by various chemists and by various methods. The variations observed in the published analyses of a given fruit are due to differences in climatic and soil conditions, stage of ripeness, degree of freshness of the fruit, method of analysis, and perhaps to other factors. The analyses reported were all made by the writer according to one uniform method. All the fruits and nuts came from one locality. Only normal, fully ripe fruits were used. They were picked in the morning and analyzed on the same day. The results, therefore, reliably represent the relative percentages of various constituents in an unusually large list of fruits and nuts from one locality.

In the case of the mango, avocado, papaya, and citrus fruits, several varieties of each were analyzed. Interesting variations in the composition of varieties of the same species were found.

The chemical changes which take place during the ripening of fruits are of great interest from a scientific as well as from a practical standpoint. The station had previously studied the ripening of pineapples. A similar study was made of bananas and papayas. Interesting data on the ripening process in these two fruits are herein presented.

METHOD OF ANALYSIS.

The analytical methods employed were essentially those of the official chemists. The total solids were determined by mixing with asbestos and drying at 100° C. In a few cases it was found difficult to determine insoluble solids when the soluble solids were very slow to filter through the linen filter. The fruit sample began to jelly before it all passed through. Usually the determination was made without this difficulty. Acid was determined by titration against fifth-normal KOH, using phenolphthalein as indicator in the uncolored solutions; otherwise litmus paper was used. In clarifying the fruit solutions for sugar determination alumina cream was used in the analyses recorded in the tables on mango and papaya. In all other cases lead subacetate was used instead, since alumina cream proved inefficient in these fruits. Reducing sugars were determined by the volumetric Fehling solution method of Munson and Walker, the more acid fruit solutions being neutralized. Sucrose, with a few exceptions, was determined by Clerget's method. Fat was obtained by extraction with ether. When starch was known to be an especial constituent the total hydrolyzable carbohydrates were determined by acid hydrolysis. Diastase was used in the starch determination in studying the ripening of bananas and papayas.

ANALYTICAL DATA.

In the table on page 66 is shown the composition of several varieties of mangoes. The total solids are high for the average fresh fruit; the total sugars vary from 11 to 20 per cent, according to the variety. In all samples the sucrose is the principal sugar present. The protein in several varieties is a little higher than is usual in fruits. The acidity varies and is as much as 0.5 per cent in one variety.

Qualitative tests showed the presence of considerable amounts of tannin, but no starch was apparent.

The analysis of the avocado shows it to contain rather high total solids. The high percentage of soluble solids is probably due in part to oil which passed through the linen filter. The protein and ash are high for fruit. Very noticeable are the small amounts of sugars and the large amount of fat. The fat varies in the several varieties, being as high as 21.79 per cent in one fruit. The acid content of the fruit is very low.

As the composition of the banana is discussed more in detail later little need be said here about the analyses. They show the high and variable sugar content of the ripe banana, being highest in the baking varieties. The ash and protein are high. The acidity is low, being highest in the Apple banana.

The breadfruit is included in the table with bananas because it contains such high amounts of carbohydrates. In comparing it with the banana the hydrolyzable carbohydrates are seen to be much greater in amounts. The breadfruit contains considerable amounts of starch even when ripe. The ash, fiber, and protein are high.

The Samoan breadfruit was analyzed at a riper stage than the Hawaiian specimen, which may account for the larger proportion of starch to sugars in the former.

The jack fruit, belonging to the same family with breadfruit, and curious because of its huge size and strong peculiar odor, is rather high in protein and fiber and low in acid. The analysis of the total pulp shows less sugar than that of the edible portion, which consists of a yellow custard-like pulp surrounding each seed. The seed of the jack fruit has a very high content of starch and but very little sugar. The protein is over 5 per cent.

The composition of the papaya is discussed below in more detail. In comparing the several varieties the total solids are seen to vary several per cent.

The acidity and protein vary also with the variety as do the sugars. As experiments in breeding new varieties of papayas are being carried out by the horticultural department of this station to develop flavor, sugar, and firmness, these analyses are of interest as showing the changes brought about. It will be noticed that the principal sugar of the papaya is invert sugar, and only traces of sucrose are found.

Citrus fruits are known for their high acid content, which makes them especially refreshing when made into beverages. The common orange is milder than the lime or lemon, containing less acid and more sugar than the latter fruit. Sucrose and reducing sugar are both present in the orange.

The fiber is rather high in the oranges and shaddock. The high fat content in the limes and lemons may in part be due to oil from the skin. The samples were prepared by peeling off the skin in case of the orange and grinding up the whole pulp. The lemons and limes were squeezed as in obtaining the juice, which accounts for the low total solids found.

The samples of guavas analyzed were obtained by grinding up pulp and seeds together, as it is difficult to separate the seed. The skin was removed in all except the strawberry guavas, which are eaten whole.

The sugar content of the guava is not high. The strawberry guava contains more acid than the other varieties, but is less acid to the taste.

The sweet sop and cherimoya contain considerable sugar, principally reducing sugar. The protein and fiber are high and the acid low.

The roselle is of commercial interest, as it is used to a great extent in making jams and jellies which resemble cranberry jelly. The calyx is unusually low in sugars and hydrolyzable carbohydrates and quite high in acid. Its food value is almost nil, but its strong acidity, fine red color, and jellying qualities make it of especial value as a cooking fruit. The seed pods have a somewhat higher carbohydrate content and are less acid.

The tamarind is of interest because of its high acid and sugar content. It is supposed to contain more acid and sugar than any other fruit. The tamarinds analyzed in this laboratory were lower in reducing sugar than those grown in the Philippines, but the fruit may have been slightly green. The analysis reported by Pratt and Del Rosario [1] shows the green tamarind to contain little sugar, but the sugar increases very greatly on ripening.

In the analysis of the pomegranate, sample 1 was obtained by grinding up the pulp and seeds, but in sample 2 the seeds were separated from the pulp.

Of the Hawaiian berries the poha and Hitchcock berries are most commonly used. The poha makes a jam which has an unusually delicious flavor. The berries are quite acid. The ohelo grows wild on the mountain sides and is not cultivated to any extent. It has a low sugar and acid content. The Hitchcock berry is similar to the raspberry.

Prickly pear grows wild on the islands, but the red juicy fruit is not very popular as a food on account of the spines that make it difficult to pick. The fruit is juicy, sweet, and very mild in flavor.

Kamani fruit is used in making an alcoholic liquor, and is very fibrous.

The noni is a bitter fruit with a disagreeable odor; it is much used as a medicine.

Of the nuts analyzed the coconut and kukui are best known. The nuts contain considerable oil and but little sugar. The protein is high in the kukui and cashew nuts, but low in the coconut. The kukui is only eaten in small amounts, as it has a poisonous effect. The cashew requires baking before it can be eaten with impunity.

The table following gives the results of the analyses of 92 samples of Hawaiian fruits and nuts.

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[1] Philippine Jour. Sci., Sec. A, 8 (1913), No. 1, pp. 59–80.

Composition of some Hawaiian fruits, nuts, etc.

Kind of fruit.	Edible portion.	Waste.	Total solids.	Insoluble solids.	Ash.	Acids as H_2SO_4.	Protein.	Sugars.			Polarization.			Fat.	Fiber.	Hydrolyzable carbohydrates other than sucrose.
								Reducing.	Sucrose.	Total.	Direct.	Invert.	Temperature.			
Mango (*Mangifera indica*):	*Per ct.*	*Per ct.*	*Per ct.*	*Per ct.*	*Per ct.*	*Per ct.*	*Per ct.*	*Per ct.*	*Per ct.*	*Per ct.*	° *V.*	° *V.*	° *C.*	*Per ct.*	*Per ct.*	*Per cent.*
Pirie	60.00	40.00	20.52	3.14	0.343	0.221	0.456	3.55	11.23	14.78	+ 8.84	−5.45	31	0.032	0.508	....
Pirie	65.28	34.72	21.02	1.75	.466	.127	.838	3.31	14.02	17.33	+11.8	−6.10	30	.165	.404	....
Alphonse	67.48	32.52	20.92	2.42	.469	.373	.919	3.74	10.90	14.64	+ 9.7	−4.2	30	.149	.715	....
Oahu	61.66	38.34	19.61	3.82	.445	.122	.531	2.06	13.66	15.72	+12.4	−4.8	33.5	....	.713	....
Totafari	60.19	39.81	15.27	2.11	.277	.578	.475	3.55	7.93	11.48	+ 4.8	−5.2	33.5	.065	.539	....
Jamshedi	66.25	33.75	20.07	4.35	.415	.264	.944	1.53	11.53	13.06	+10.2	−4.4	32	.133	.656	....
Gay	59.60	40.40	23.42	4.02	.419	.379	1.075	3.01	16.99	20.00	+14.2	−7.2	33.5	.530	.695	....
Brindabani	69.75	30.25	19.75	5.88	.274	.269	.438	4.55	10.43	14.98	+ 8.0	−5.2	32.2	.126	.518	....
Avocado (*Persea gratissima*):																
Makaha I	74.57	25.43	21.01	10.43	1.003	.137	1.456	.83	.00	.83	+ 2.0	+2.4	31.4	13.05	1,282	....
Makaha II	73.47	26.53	25.87	13.97	1.031	.093	....	.64	.00	.64	+ 3.2	+3.2	31.5	17.25	1.378	....
Davis No. 7	64.57	35.43	21.29	13.78	.915	.069	2.094	1.28	.39	1.67	+ .5	.0	33	11.92	1.639	....
Davis No. 6	51.34	48.66	30.74	20.57	1.038	.078	1.700	.44	.00	.44	+ .2	+ .2	31.8	21.79	1.672	....
Davis No. 4	63.39	36.61	28.15	18.91	1.034	.104	2.238	.56	.00	.56	+ .6	+1.2	30.5	19.01	1.707	....
Banana (*Musa* spp.):																
Chinese	70.00	30.00	21.28	2.45	.955	.245	1.788	8.18	8.48	16.66	+ 7.9	−3.2	23.7	.180	.253	None.
Apple	74.49	25.51	31.52	....	.964	.417	1.238	14.56	9.59	24.15	+ 6.6	−5.6	31	.223	.351	....
Brazilian	68.25	31.75	27.78	7.21	.924	.406	1.775	17.23	2.45	19.68	− .9	−4.0	31.5	.201	.305	2.57
Baking	75.72	24.28	32.22	5.49	.750	.397	1.350	21.16	5.04	26.20	+ 1.6	−4.8	31.6	.518	.333	2.53
Fehi	64.29	35.71	27.87	10.30	....	.230	1.069	14.49	.00	[1] 14.49	....	....	....	.046	.594	....
Breadfruit (*Artocarpus incisa*):																
Hawaiian	77.75	22.25	41.82	20.35	.952	.049	1.575	1.75	7.74	9.49	+ 8.2	−1.6	32	.190	1.204	27.89
Samoan	83.44	16.56	26.89	8.44	1.152	.078	1.575	4.93	9.67	14.60	+10.4	−2.0	29	.517	.978	9.21
Jack fruit (*Artocarpus integrifolia*):																
Whole fruit	57.73	42.27	18.92	8.86	.962	.181	1.688	5.55	2.18	7.73	+ 1.6	−1.2	29	.599	1.904	....
Pulp	32.00	68.00	23.20	5.76	.934	.274	1.444	6.51	8.64	15.15	+ 7.5	−3.6	28.5	.450	1.311	....
Seeds	87.00	13.00	50.82	34.94	3.497	.162	5.444	.71	1.16	1.87	+ 1.9	+ .4	28.0	.241	1.609	23.53
Papaya (*Carica papaya*):																
Trinidad (2976)	75.56	24.44	12.14	1.66	.539	.061	.438	8.98	.74	9.72	+ 1.8	+ .86	31	.065	.780	....
South Africa (2973)	72.29	27.71	13.00	2.32	.549	.098	.681	10.20	.53	10.73	+ 2.4	+1.7	29.2	.074	.818	....
South Africa (2973)	73.50	26.50	14.06	2.52	.612	.098	.519	10.62	None.	10.62	+ 1.8	+1.76	33.4	.041	.851	....
Honolulu (2355: 3)	71.75	28.25	12.20	1.81	.560	.078	.500	10.29	None.	10.29	− .4	− .5	31.5	.059	.663	....
Barbados (2848)	84.11	15.89	11.72	2.44	.481	.069	.463	8.95	None.	8.95	+ .8	+ .86	32.5	.068	.765	....
Tahit (2975)	74.76	25.24	10.19	2.07	.677	.171	.906	7.50	.94	8.44	+ .7	− .5	31.5	.045	.789	....
Tahiti (2975)	78.14	21.86	9.50	1.90	.630	.113	.694	6.71	.39	7.10	+ .7	+ .2	30.0	....	....	....
Barbados (2764)	77.47	22.53	10.58	1.88	.517	.103	.731	7.47	.31	7.78	+ 2.0	+1.6	31.0	.055	.754	....

Barbados (2848)	82.44	17.56	9.22	1.99	.372	.078	.519	6.10	.31	6.41	+ 2.0	+1.6	30.8	.091	.842	...
Panama (2979)	47.71	52.29	16.51	1.78	.878	.186	.750	13.21	2.04	15.25	+ 1.0	−1.6	31.0	.115	1.003	...
Panama (2978)	48.58	51.42	14.41	2.09	.905	.147	.506	9.86	1.26	11.12	+ 1.8	+ .2	30.5	.253	1.094	...
2355	83.39	16.61	10.59	1.05	.565	.059	.388	8.02	None.	8.02	− .2	.0	31.0	.186	6.693	...
Orange:																
Kona	72.13	27.87	12.15	2.57	.453	.882	.681	2.09	3.81	5.90	+ 3.5	−1.4	28.3	.387	.575	...
Waialua	70.50	29.50	9.56	2.60	.505	1.058	.819	4.25	2.99	7.24	+ 3.2	− .6	31.4	...	3.66	...
Japanese	71.26	28.74	11.20	2.16	.353	.749	.831	3.82	2.83	6.65	+ 3.0	− .6	30.6	.448	.479	...
Chinese	68.75	31.25	10.81	3.01	.522	3.758	...	...	...	...	...	...	...	.303	.777	...
Shaddock	42.39	57.61	11.53	6.14	.486	.196	1.175	.86	7.26	8.12	+ 7.6	−1.6	31.8	.140	1.977	...
Limes	49.17	50.83	11.75	.11	.352	6.830	.675	1.50	None.	1.50	− 0.4	− .2	31.5	3.561	.065	...
Lemons (rough)	33.14	66.86	6.44	.30	.232	3.371	.356	1.53	.47	2.00	+ 2.2	+1.6	32.3	1.49	.084	...
Guava (*Psidium guajava*):																
Common	84.69	15.31	17.78	7.27	.531	.363	1.125	6.61	.77	7.38	− 1.8	−2.8	30.2	.524	4.445	...
White	87.76	12.24	18.75	7.73	.676	.451	1.525	5.73	2.53	8.26	− .2	−3.4	32.3	.412	5.105	...
Trinidad	86.62	13.38	15.43	8.99	.651	.261	1.506	5.79	.55	6.34	− 2.5	−3.2	31.0	.353	4.425	...
Guava (*Psidium cattleianum*):																
Chinese strawberry	98.01	1.99	20.08	7.36	.635	.696	...	3.64	6.37	10.01	+ 4.70	−3.4	31.0	.418	3.868	...
Common strawberry	98.60	1.40	18.27	9.97	.743	1.171	1.038	2.41	2.05	4.46	+ 1.8	− .8	31.7	.554	6.146	...
Common strawberry	81.16	18.84	23.75	14.47	.755	.715	1.838	2.32	3.31	5.63	+ 2.4	−1.8	32.0	.790	9.378	...
Fig: (*Ficus carica*):																
——— ———	80.39	19.61	16.96	2.85	.475	.127	.988	12.98	None.	12.98	− 1.8	−1.6	31.6	.368	1.275	...
2384: 1	81.96	18.04	17.72	2.09	.548	.137	1.250	12.75	0.39	13.14	− 1.5	−2.0	33.2	.210	1.149	...
Tantalus	78.34	21.66	10.27	2.18	.454	.167	1.963	6.28	None.	6.28	− .5	− .4	30.5	.261	1.073	...
Pineapple (*Ananas sativus*)[2]	...	...	...	...	...	.66	.375	3.92	6.78	10.70	+ 5.0	−3.6	31.7	...	...	...
Grape (*Vitis labrusca*):																
Isabella	56.25	43.75	15.73	6.67	.205	.490	.394	16.19	None.	16.19	− 5.0	−4.8	28.7	.238	.289	...
Sweet sop (*Anona squamosa*)	53.47	46.53	21.33	4.07	.844	.215	2.038	16.51	None.	16.51	− 3.4	−3.6	31.7	.547	1.632	...
Do	55.73	44.27	24.82	5.48	.673	.127	1.531	15.27	2.88	18.15	− .7	−4.4	27.7	.548	1.225	...
Cherimoya (*Anona cherimola*)	84.23	15.77	33.81	9.86	.669	.064	1.838	15.34	3.07	18.41	+ .3	−3.6	31.4	.145	4.293	...
Star apple (*Chrysophyllum cainito*)	86.90	13.10	11.47	5.46	.392	.127	2.338	2.67	1.73	4.40	+ 1.6	− .6	31.5	1.385	.857	...
Mountain apple (*Eugenia malaccensis*)	73.87	26.13	8.61	...	.137	.068	.213	6.88	None.	6.88	− 2.1	−2.1	29.0	.035	.562	...
Rose apple (*Eugenia jambos*)	62.94	37.06	15.85	3.70	.299	.039	.794	11.26	.47	11.73	− 1.2	−1.8	30.3	.189	.982	...
Java plum (*Eugenia jambolana*)	57.50	42.50	15.63	3.54	.287	.838	.619	12.99	None.	12.99	− 3.0	−2.8	32.7	.524	.164	...
Surinam cherry (*Eugenia michelli*)	84.38	15.62	9.30	1.93	.342	1.440	1.019	4.68	1.38	6.06	− 1.0	−2.8	25.0	.664	.343	...
Loquat (*Eriobotrya japonica*)	60.00	40.00	10.02	2.71	.385	.666	.413	1.79	2.09	3.88	+ .5	−2.2	27.5	.500	.653	...
Roselle (*Hibiscus sabdariffa*):																
Calyx	55.43	44.57	11.58	5.03	.651	2.263	1.231	.20	None.	.20	+ .4	+ .4	29.0	.819	1.454	1.57
Seed pods	...	...	23.73	16.91	1.078	.637	4.000	.27	1.09	1.36	+ 1.0	− .4	29.5	1.152	6.621	4.18
Ceriman (*Monstera deliciosa*)	73.88	26.12	22.12	2.12	.851	.353	1.181	16.19	None.	16.19	− 4.4	−4.6	33.5	.205	.569	...
Natal plum (*Carissa grandiflora*)	78.12	21.88	21.55	4.29	.437	1.196	.563	12.00	None.	12.00	− 5.6	−5.2	32.3	1.03	.918	...
Carambola (*Averrhoa carambola*):																
Sweet	100.00	None.	8.22	3.13	.421	.784	.719	3.40	None.	3.40	− .7	− .7	31.3	.755	1.237	...
Sour	100.00	None.	8.69	2.84	.408	.309	...	5.25	.16	5.41	− .6	− .8	29.5	.314	.992	...
Tamarind (*Tamarindus indica*)	48.28	51.72	69.51	17.68	1.823	11.329	3.431	18.74	2.58	21.32	+ 3.3	.0	31.2	.851	5.615	...
Pomegranate (*Punica granatum*):																
Whole fruit	56.06	43.94	26.33	10.14	.591	.122	1.488	12.21	None.	12.21	− 3.2	−3.2	30.2	.477	5.297	...
Pulp	46.88	53.12	17.52	1.98	.735	.137	.525	15.00	1.07	16.07	− 2.6	−4.0	30.0	.304	.329	...
Poha (*Physalis peruviana*)	100.00	None.	17.86	6.78	.733	1.009	...	2.67	5.97	8.64	+ 6.4	−1.2	30.7	.331	4.730	...
Do	100 00	None.	17.76	7.09	.829	1.214	2.006	2.25	5.49	7.74	+ 6.6	− .4	30.5	.298	3.828	...

[1] Determined by copper reduction method.

[2] Hawaii Sta. Rpt. 1910, p. 47.

Composition of some Hawaiian fruits, nuts, etc.—Continued.

Kind of fruit.	Edible portion.	Waste.	Total solids.	Insoluble solids.	Ash.	Acids as H_2SO_4.	Protein.	Sugars.			Polarization.			Fat.	Fiber.	Hydrolyzable carbohydrates other than sucrose.
								Reducing.	Sucrose.	Total.	Direct.	Invert.	Temperature.			
	Per ct.	*Per ct.*	*Per ct.*	*Per ct.*	*Per ct.*	*Per ct.*	*Per ct.*	*Per ct.*	*Per ct.*	*Per ct.*	° *V.*	° *V.*	° *C.*	*Per ct.*	*Per ct.*	*Per cent.*
Ohelo berry (*Vaccinium reticulatum*)	100.00	None.	8.51		0.175	0.485	0.431	3.42	0.32	3.74	− 1.2	−1.6	33.0			
Hitchcock berry (*Rubus* sp.)	100.00	None.	13.22	7.01	.397	.534	1.300	5.48	None.	5.48	− .8	− .4	30.5	0.391	3.953	
Liberian coffee (*Coffea liberica*):																
Pulp			28.21	13.34	1.630	.255	2.863	5.30	None.	5.30	+ .4	+ .4	31.9	.288	3.315	
Bean			45.18	35.52	1.578	.069	5.338	2.56	3.94	6.50	+ 3.6	−1.4	31.6	.685	14.703	
Prickly pear (*Opuntia tuna*):																
Red	78.96	21.04	16.54	2.40	.579	None.	.938	12.75	.55	13.30	+ .3	− .4	30.0	.240	1.296	
Green			19.66	4.69	.404	.181	.981	13.42	None.	13.42	− 1.4	− .8	31.0	.232	2.791	
Longan (*Nephelium longan*)	58.52	41.48	17.61				1.419	5.99	2.35	8.34	+ 1.0	−2.0	30.3	.452	.638	
Allspice (*Pimenta officinale*)	100.00	None.	28.28	18.42	1.110	.392	1.581	11.09	None.	11.09	− 3.4	−3.1	33.8	2.033	4.040	
Wi apple (*Spondias dulcis*)	65.00	35.00	14.53	2.48	.442	.478	.500	7.09	3.45	10.54	+ 1.3	−3.1	30.5	.286	.853	
Hog plum (*Spondias lutea*)	47.50	52.50	11.47	.83	.655	.980	1.375	9.41	None.	9.41	− 1.5	− .8	29.7	.565	1.165	
Kamani (*Terminalia catappa*)	63.94	36.06	19.52	8.62	.963	.162	.788	7.78	.94	8.72	− .4	−1.6	31.2	.229	3.300	
Carryong (*Brachychiton* sp.)	36.84	63.16	13.78	2.21	.890	.715	1.525	1.31	7.72	9.03	+ 7.4	−2.4	31.3	.620	.808	
Noni (*Morinda citrifolia*)	59.93	40.07	10.97	3.16	.838	.303	.631	3.37	.14	3.51	− 1.1			.260	1.052	
Oil palm (*Elæis guineensis*):																
Fruit	49.76	50.24	28.70			.431	1.088	4.45	None.	4.45	− 1.2	−1.3	33.0	.258	8.907	
Algaroba (*Prosopsis juliflora*):																
Meal	100.00	None.	92.51	50.17	3.535	.331	9.863	3.07	27.59	30.68	+26.4	−9.2	27.3	1.160	24.578	
Coconut (*Cocos mucifera*)	26.40	73.60	54.66	31.43	1.020	.129	4.206	Trace.	6.41	6.41	+ 5.4	−2.8	29.5	33.406	5.450	
Macadamia nut (*Macadamia ternifolia*)			92.99	72.14	1.622	.098		Trace.	2.67	2.67	+ 1.8	−1.6	30.6	66.730	1.920	
Kukui nut (*Aleurites triloba*)	12.1	87.9	92.86		3.05		19.88							66.250	1.39	[1] 1.40
Cashew nut (*Anacardium occidentale*)	29.48	70.52	93.22		2.588		14.437							41.568	1.273	

[1] Total hydrolyzable material.

STUDY OF THE RIPENING PROCESS OF THE CHINESE BANANA AND THE PAPAYA.

It is of considerable interest to compare the composition and ripening process of two such fruits as the banana and the papaya. The banana, grown in the Tropics and commonly known in the Temperate Zone because it stands transportation so well, is characterized by its high carbohydrate content. The papaya, not so well known in the North, resembles the average fruit which contains little nourishment but is of value for its high water content, fruit acids, and enzyms. The papaya is characterized by an enzym allied to pepsin, which is considered to be an aid to digestion.

In this study of the fruits a few microscopic tests were first made on the unripe and the ripe samples. The banana when green and tested for starch by iodin turned en masse to an intensely blue-black color, but when ripe only a few granules scattered here and there turned dark, showing the great decrease in starch on ripening. A test for tannin on cross sections of both the green and ripe banana, using ferric chlorid solution, showed tannin to be arranged in a narrow line around the outer margin of the fruit and along the three divisions that radiate from the center.

In contrast to the banana the green or ripe papaya showed with iodin no indication of starch to the unaided eye, except for an almost imperceptible circle where the stem had been cut from the fruit. Under the microscope a few grains of starch could be discerned in the fruit itself. There was apparently no tannin present in either the green or the ripe papaya.

The chemical analysis of the two fruits was made according to the official methods,[1] modified in a few instances, as stated below.

Sucrose was determined by polarization before and after inversion. Reducing sugars were determined according to the volumetric method of Munson and Walker.[2] In every case lead subacetate was used as a clarifying reagent.

Hydrolyzable carbohydrates were determined by boiling the substance with 200 cubic centimeters water and 20 cubic centimeters hydrochloric acid (specific gravity 1.125). Starch in the banana was determined by digestion with diastase and after filtration hydrolysis of an aliquot with hydrochloric acid.

COMPOSITION OF THE CHINESE BANANA.

A bunch of Chinese bananas was picked while the fruit was very green and slightly undersized and hung up in a room near the laboratory, where it was allowed to ripen. An analysis was made of the very green fruit at a period when the peel adhered closely to the flesh.

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[1] U. S. Dept. Agr., Bur. Chem. Bul. 107 (rev.).

[2] Ibid., p. 42.

When the remaining bananas showed a slight yellow tint, a sample was again taken for analysis. Another sample was analyzed when the fruit was entirely ripe.

The determination of reducing sugar made on the water solution of the entirely green banana presented some difficulty, as the sugar content was extremely low, and some gum, which could not be precipitated with lead subacetate, caused a greenish-yellow precipitate to form on boiling with the Fehling solution. This difficulty was overcome by boiling the sugar sample with 95 per cent alcohol, according to the method of E. M. Bailey,[1] filtering, and evaporating the alcohol from the solution, to which lead subacetate was then added and the reducing sugars determined.

The results obtained on the first bunch of bananas are given under "a" in the table on page 73.

As the banana forms a gummy mass with water, it is almost impossible to separate sugars entirely from the starch and other carbohydrates by means of water. In some analyses both starch and the hydrolyzable carbohydrates were determined in the whole sample without first extracting the sugars. It was found that sugars were somewhat decomposed on boiling with the dilute acid, so that an error occurred by this method and the total hydrolyzable carbohydrates found in the ripe fruit was less than the total sugars found in the water solution.

A second bunch of green bananas was therefore obtained and allowed to ripen for analysis. In the samples from this bunch the sugars were first extracted with boiling alcohol[2] and the starch and hydrolyzable carbohydrates determined in the residues. It was found by this method that the sugars could be separated rapidly from the banana, since alcohol does not form the gummy mass with the material as does water. The starch was not separated from the dextrins before treatment with diastase and subsequent hydrolysis, but a separate determination of gums, soluble in water, showed them to be present to the extent of 0.59 per cent in the green and 0.43 per cent in the ripe fruit. In the ripe fruit the determination of gums was made on the residue after extraction with boiling alcohol; and as the boiling alcohol may easily have extracted certain dextrins, there may have been a higher percentage of gums than determined. Under "b" in the table are shown the results obtained by extraction with alcohol.

The results from both samples show that the total solids decrease slightly during the ripening process. The insoluble solids are almost as high as the total solids in the green banana, but decrease very rapidly on ripening and in the ripe fruit amount to less than 3 per

[1] Jour. Amer. Chem. Soc., 34 (1912), No. 12, p. 1729. [2] E. M. Bailey, loc. cit.

cent. The ash is high throughout and does not change appreciably. The acid content is but a few tenths of a per cent and appears to reach its maximum when the fruit is half ripe, after which it decreases. The protein is fairly high and remains constant.

Quite striking is the change in starch and sugars, during the process of ripening of the banana. When green, the starch is exceedingly high, amounting to about 20 per cent, while the sucrose and reducing sugars amount to a few tenths of a per cent. At the half-ripe stage, the sugars have increased several per cent and in about the same proportion that the starch has decreased. In the fully ripened stage the sugars have increased greatly and the starch has almost disappeared.

The hydrolyzable carbohydrates, other than starch or sucrose, are small in amounts.

Fat occurred in small quantities, increasing from 0.025 per cent in the green fruit to 0.180 per cent in the ripe. Fiber was also present in small amounts.

In the water solution after boiling, none of the usual tannin reactions were obtained. Tannin was, therefore, not determined.

COMPOSITION OF THE PAPAYA.

The papayas used for study were obtained directly from one tree, each on the day analyzed, and were chosen by the horticulturist, who is familiar with the indications of ripening fruit. The fruits were analyzed at the fully ripe stage and at several immature stages, the very green ones being quite undersized. Those which were analyzed five months before ripeness were about half the size of the mature papaya. The yellow tint does not appear in the fruit until about three weeks before full ripeness. As the fruit contained practically no starch according to qualitative test, this determination was not made, but the total hydrolyzable carbohydrates were determined by boiling the material with dilute hydrochloric acid solution and subtracting from the total the reducing sugars found in the water solution. The results are shown in the table on page 73.

It is at once seen that the total solids are low throughout the ripening process and increase as the fruit ripens. The insoluble solids are about 3 per cent in the green fruit and decrease to about 1 per cent in the ripe fruit. The ash, acid, and protein occur in small quantities and are quite constant. The fruit contains not more than a trace of sucrose. The reducing sugars in the green fruit, however, amount to over 2 per cent but increase rapidly as the fruit increases in size and approaches ripeness. The hydrolyzable carbohydrates are almost nil, and fat, fiber, and undetermined matter occur only in small amounts. It is logical to conclude, therefore, that, as the fruit

when green has no store of carbohydrates upon which to draw, it must obtain its sugars by translocation from the trunk of the trees.

In comparing the banana with the papaya it is noted that the banana contains higher percentages of total solids, carbohydrates, protein, acid, and ash, and is altogether a more substantial fruit. It is of interest to note that the total solids decrease in the banana during the ripening process but increase considerably in the papaya. The banana contains large amounts of starch and other carbohydrates when green. It may, therefore, be separated from the tree at that time and on ripening still contain a normal amount of sugar due to the hydrolysis of its starch. In the papaya no such store of food is held.

It is also interesting to note that the banana contains sucrose and reducing sugars. The papaya, on the other hand, has practically no sucrose but considerable reducing sugars. The fat content is more constant in the papaya during ripening and the fiber is higher than in the banana.

In both fruits the acid-sugar ratio is low.

Some of the changes in the composition of the Chinese banana and of the papaya during the ripening process are shown in the accompanying table.

Composition of the Chinese banana and the papaya at different stages of ripeness.

Stage of ripeness.	Edible portion.	Waste.	Total solids.	Insoluble solids.	Ash.	Acids as H_2SO_4.	Protein.	Sugars.			Polarization.			Starch by diastase method.	Hydrolyzable carbohydrates other than starch or sugar.	Fat.	Fiber.	Undetermined matter.
								Reducing.	Sucrose.	Total.	Direct.	Invert.	Temperature.					
Chinese banana.	*Per ct.*	*Per ct.*	*Per ct.*	*Per ct.*	*Per ct.*	*Per ct.*	*Per ct.*	*Per ct.*	*Per ct.*	*Per ct.*	° *V.*	° *V.*	° *C.*	*Per ct.*	*Per ct.*	*Per ct.*	*Per ct.*	*Per ct.*
Green (a)	57.48	42.52	23.51	16.25	0.871	0.196	2.013	0.15	0.31	0.46	+ 1.6	+1.2	25.3	17.38	1.16	0.025	0.276	1.13
Green (b)	....	....	28.51	25.25	.891	.114	1.275	.10	.53	.63	+ .6	− .1	25.3	19.97	1.23	.055	.370	3.97
Half ripe (a)	63.64	36.36	21.98	10.78	.948	.343	1.838	4.93	4.17	9.10	+ 4.2	−1.2	26.2	5.02	2.28	.151	.335	1.96
Half ripe (b)	57.76	42.24	27.56	14.90	.921	.320	1.331	3.53	7.31	10.84	+ 6.8	−2.6	28.3	7.93	1.64	.091	.314	4.17
Ripe (a)	70.00	30.00	21.28	2.45	.955	.245	1.788	8.18	8.48	16.66	+ 7.9	−3.2	23.7	None.	None.	.180	.253	1.20
Ripe (b)	67.00	33.00	24.47	2.66	.883	.156	1.119	7.41	11.26	18.67	+10.4	−4.2	25.6	.43	.49	.257	.309	2.16
Papaya.																		
5 months before ripeness	71.00	29.00	6.48	3.28	.621	.065	.800	2.15	.23	2.38	+ 1.5	+1.2	30.7	....	.26	.205	.873	1.28
5–6 weeks before ripeness	80.97	19.03	6.13	2.38	.451	.045	.381	2.88	None.	2.88	+ 1.0	+1.2	28.0	....	.49	.186	.602	1.09
4 weeks before ripeness	81.24	18.76	6.13	2.31	.427	.045	.388	2.81	.23	3.04	+ .7	+ .4	27.8	....	.01	.188	.692	1.34
3 weeks before ripeness	81.13	18.87	6.26	2.46	.471	.026	.306	2.93	None.	2.93	+ .7	+ .8	26.7	....	.45	.208	.716	1.1
2 weeks before ripeness	78.73	21.27	6.45	2.49	.425	.044	.306	4.13	.47	4.60	+ .6	.0	31.0	....	.00	.261	.581	.23
8 days before ripeness	84.65	15.35	8.92	2.37	.508	.033	.356	5.99	None.	5.99	− .2	− .2	30.0	....	.12	.163	.654	1.10
1 day before ripeness	84.99	15.01	10.68	1.18	.514	.059	.463	7.82	.47	8.29	− .6	−1.2	27.5	....	....	.168	.592	.65
Entirely ripe	83.39	16.61	10.59	1.05	.565	.059	.388	8.02	None.	8.02	− .2	.0	31.0	....	.00	.186	.693	.68

Issued June 23, 1916.

HAWAII AGRICULTURAL EXPERIMENT STATION,

J. M. WESTGATE, Agronomist in Charge.

REPORT OF THE HAWAII AGRICULTURAL EXPERIMENT STATION.

1915.

UNDER THE SUPERVISION OF

STATES RELATIONS SERVICE,
Office of Experiment Stations,
U. S. DEPARTMENT OF AGRICULTURE.

WASHINGTON:
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HAWAII AGRICULTURAL EXPERIMENT STATION, HONOLULU.

[Under the supervision of A. C. TRUE, Director of the States Relations Service, United States Department of Agriculture.]

E. W. ALLEN, *Chief of Office of Experiment Stations.*

WALTER H. EVANS, *Chief of Division of Insular Stations, Office of Experiment Stations.*

STATION STAFF.

J. M. WESTGATE, *Agronomist in Charge.*
J. EDGAR HIGGINS, *Horticulturist.*
M. O. JOHNSON,[1] *Chemist.*
D. T. FULLAWAY,[2] *Entomologist.*
F. G. KRAUSS, *Superintendent of Extension Work.*
J. B. THOMPSON,[3] *Assistant Agronomist, in Charge of Glenwood Substation.*
ALICE R. THOMPSON, *Assistant Chemist.*
V. S. HOLT, *Assistant Horticulturist.*
C. A. SAHR, *Assistant Agronomist.*
A. T. LONGLEY, *Executive Assistant.*

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[1] Appointed July 25, 1915, to succeed Wm. T. McGeorge, transferred to U. S. Department of Agriculture, Bureau of Chemistry.
[2] Resigned June 30, 1915.
[3] Appointed July 6, 1915, to succeed F. A. Clowes, resigned.

LETTER OF TRANSMITTAL.

HAWAII AGRICULTURAL EXPERIMENT STATION,
Honolulu, Hawaii, September 14, 1915.

SIR: I have the honor to transmit herewith and to recommend for publication a report of the Hawaii Agricultural Experiment Station, 1915.

Respectfully,

J. M. WESTGATE,
Agronomist in Charge.

Dr. A. C. TRUE,
Director States Relations Service,
U. S. Department of Agriculture, Washington, D. C.

Publication recommended.
A. C. TRUE, *Director.*

Publication authorized.
D. F. HOUSTON,
Secretary of Agriculture.

CONTENTS.

ILLUSTRATIONS.

REPORT OF THE HAWAII AGRICULTURAL EXPERIMENT STATION, 1915.

SUMMARY OF INVESTIGATIONS.

By J. M. WESTGATE, *Agronomist in Charge.*

INTRODUCTION.

The station has continued as in the past to aid in the development of diversified agricultural industries in the islands. There are a number of crops that have been found agriculturally possible which at present are not able to compete economically with sugar, and the station has continued its experimental and extension work to place some of these on a profitable basis. It is felt that the most stable prosperity is that which is based upon a number of lines of industry rather than upon a single crop. To this end the station is collecting data as to the agricultural possibilities of different crops on the different soils of the various islands. As rapidly as possible the cultural requirements of these various crops in relation to soils, altitudes, and moisture supply are being worked out.

BUILDINGS AND GROUNDS.

During the year only minor repairs and additions were made in connection with the station buildings. The roofs of three of the buildings were treated with roof-preserving paint in order to prolong the life of the shingles. The foundations of the same buildings were also repaired where decay and insect pests had weakened or destroyed the timbers. It was found necessary to rebuild one of the large water tanks holding a reserve water supply of 60,000 gallons.

The Marine-Hospital Service tract of land adjoining the station grounds was resurveyed and laid out in plats for the department of agronomy. The survey indicated that there were about 3 acres available for cultivated crops. This ground was replowed and planted to corn, potatoes, and various green-manure crops.

Owing to the uneveness of the soil as well as to the high cost of water for irrigating, especially for rice and taro, the lease of the Wyllie Street tract was terminated at the end of the year. Arrangements have been made with private rice and taro growers for cooperative experiments along the same lines as those carried out on this tract, and at considerably less expense to the station.

Preliminary arrangements were made with the officers in charge of the Army reservations for the lease of a tract of 10 acres of land for the purpose of determining the possibility of forage production for the Army horses. The rainfall is somewhat limited, but it is expected that proper methods of tillage and spacing will make possible economical yields of certain species of forage grasses.

CHANGES IN THE STATION STAFF.

During the year a considerable number of changes were made in the scientific staff of the station. On January 1, 1915, E. V. Wilcox, special agent in charge, was transferred to Washington, D. C., and was succeeded by J. M. Westgate, who was transferred from the Office of Forage Crop Investigations, United States Department of Agriculture. D. T. Fullaway, entomologist, returned from his year's furlough on June 1, 1915, but resigned June 30, 1915, to accept a position with the Territorial Board of Agriculture and Forestry in connection with the search for parasites of the melon fly (*Dacus cucurbitæ*). W. P. Kelley, chemist, resigned October 27, 1914, to become professor of agricultural chemistry in the Graduate School of Tropical Agriculture and Citrus Experiment Station at Riverside, Cal. He was succeeded by Wm. T. McGeorge, formerly assistant chemist at this station. Mr. McGeorge in turn left the station June 30, 1915, on a transfer to the Bureau of Chemistry, United States Department of Agriculture. Mr. McGeorge's transfer, however, did not become effective until July 8, 1915. F. A. Clowes, superintendent of Hawaii substations, resigned June 30, 1915, to take charge of the agricultural department of the Lahainaluna Industrial School, where he will be retained as a collaborator of this station in order that he may attend to the work done in cooperation with that institution. F. G. Krauss was appointed superintendent of extension work beginning November 1, 1914. Mr. Krauss was formerly agronomist of this station, but had resigned to become professor of agronomy at the College of Hawaii, which position he was filling at the time he was appointed to take charge of the extension work of this station. J. de C. Jerves was appointed collaborator January 1, 1915, at Homestead, Kauai; John E. Gamalielson, April 1, 1915, at Hilo, Hawaii; and John McCoy, May 1, 1915, at Kamuela, Hawaii, to assist in the extension work among the small farmers of those sections. George Copp was appointed collaborator January 1, 1915, at Waiakoa, Maui, but resigned June 30, 1915.

TERRITORIAL MARKETING DIVISION.

The Territorial legislature at its 1913 session appropriated funds for the maintenance of a marketing division for Hawaiian-grown

products and the station was given supervision of the project. Not a little of the satisfactory results of the work of the marketing division has been due to the loyal support of the local newspapers and other agencies and individuals interested in the upbuilding of the lesser agricultural industries of the islands.

During the year the division has made a large increase in the amount of produce handled, the sales amounting to $69,182.50 against $26,095.10 for the preceding year. The consignments which have been received have generally been in better condition than formerly, but there is yet much to be done in educating the shipper to pick, grade, and pack his products properly.

Practically all Hawaiian agricultural products except sugar have been handled by the division, most of them successfully. The onion crop harvested this year met a very poor market due to the large hold-over supply of 1914 mainland onions. Prices on the mainland were so low that it did not pay to ship our early Bermuda onions, but fresh pineapples, bananas, Maui beans, and a small shipment of copra have brought good returns.

The division has continued to publish and distribute to the producers of the Territory the Weekly Market Quotation Sheet. This sheet gives the current wholesale quotations on island products and keeps the farmer in touch with the condition of the market. This sheet is also published by most of the papers of the Territory. Growers generally do not realize the importance of keeping the division posted as to the amount of produce they have to send to market and when it may be expected to arrive, but there has been considerable improvement in the past few months. It is safe to say that the producer has received better prices since the division was established than ever before, whether he marketed his produce through the division or elsewhere.

Up to the present time the division has been seriously handicapped due to the poor facilities for handling such a large assortment of products as has been sent in for sale. With the appropriation of $14,400 for a new building and equipment made by the last legislature and an appropriation of $1,000 a month for the ensuing biennium for general expenses, most of the present difficulties should be overcome. The last legislature also filled a pressing need when it appropriated $7,500 to be used as a revolving fund for buying seed and crates to be resold to the farmers and for making advances on consignments. This fund has made it possible for the division to supply the growers with crates in which to ship their pineapples to the mainland without requiring payment for the crates until returns are received for the fruit.

Due to the apparent overproduction of pineapples in Hawaii and the prospect of a large portion of the 1915 crop rotting in the field

for want of a purchaser at a price less than half the cost of production, the division opened a branch office in San Francisco to sell fresh pineapples and such other products as find a better market on the mainland than at home.

HORTICULTURAL INVESTIGATIONS.

Horticultural investigations have continued along lines similar to those of recent years.

The litchi (*Litchi chinensis*) has received considerable attention. The excellence of this fruit, its high price, and its apparent adaptability to Hawaii have commended it for further investigations. The high price of the fruit is due to the limited supply and its popularity, not only among the Chinese, who are most familiar with this fruit, but also among all classes of the population. One of the reasons for the limited supply lies in the slowness of the methods of propagation in vogue, while another cause may be found in the great tardiness of seedling trees in coming into bearing. Experiments are being conducted to facilitate more rapid propagation by asexual means in the hope of overcoming both of these difficulties. Considerable progress has been made along these lines.

Attention has also been given to the preservation of the fruit for short periods in refrigeration, and also to various methods of transporting the seeds, which, under ordinary conditions, retain their viability only a few days. No deterioration in appearance or flavor of the fruit has been noted during refrigeration for the short periods which were tried. Other experiments along these lines are necessary. It was found possible to ship the seeds by mail in sphagnum moss, seeds having been sent by this means from Honolulu to Florida, where they are reported to have arrived in excellent condition.

In the mango investigations some studies have been made of the flowers and of the technique of cross-pollination. Bark grafting has been applied to the mango with considerable success, thus adding one more means for the top-working of established mango trees with choice varieties. Some of the new varieties of mango are not only superior to the common strains, but are more resistant to the Mediterranean fruit fly.

Some observations have been made of the keeping qualities of the Macdonald variety of avocado. Fruits were kept in the horticultural laboratory for 16 days without any refrigeration, and at the end of this time were in a perfect state of preservation. Bark grafting was tested on the avocado, but proved not to be so successful as scion budding, which consists in the inserting of the scion in a T-shaped incision in the bark of a mature branch.

Further pollinations of the papaya have been made, and lines of close-breeding as well as cross-breeding have been started.

A number of experiments have been made in the cross-pollination of two species of Aleurites, *A. moluccana*, the ordinary kukui of Hawaii, and *A. fordii*, known as the Chinese wood-oil tree. There are 120 fruits set, which are the result of these crosses, unless it may prove that some of them represent parthenocarpic or parthenogenetic developments.

The distribution of seeds and plants has been continued, chiefly with the varieties that have been under investigation, such as hibiscus, papaya, citrus, mango, and avocado.

ENTOMOLOGICAL INVESTIGATIONS.

On account of the absence of the entomologist for 11 months of the year, but little station work along entomological lines was accomplished. The insect collection was maintained, however, and a number of requests for assistance in combating insect pests were complied with either by personal visits or by advice as to the best methods of procedure. It had been anticipated that the entomologist while on furlough to the Territorial Board of Agriculture and Forestry, would be able to locate effective parasites for the pink bollworm of the cotton plant, but it was deemed inexpedient to assign him to this particular problem. Studies concerning the life history of the pink bollworm of cotton were made by August Busck, of the Bureau of Entomology, United States Department of Agriculture. Mr. Busck was given use of the insectary and entomological laboratory to facilitate the prosecution of his investigations.

CHEMICAL INVESTIGATIONS.

The relative value of the different forms of phosphate fertilizers has been determined in a series of pot experiments with three types of Hawaiian soils. The crops used were Japanese millet, cowpeas, buckwheat, radishes, and turnips. The results indicate that bone meal or other difficultly soluble phosphates are of little value as fertilizers in most parts of the Hawaiian Islands, since the soil already contains a large quantity of insoluble phosphate. For the best returns the phosphoric acid should be used in the form of soluble phosphate and in light applications at frequent intervals. The insoluble phosphates are of little value except in the wet districts. In soils high in iron and alumina, lime has in the past been added with applications of soluble phosphates in order to delay the formation of iron and aluminum phosphates. It has been found, however, that plants fertilized with iron and aluminum phosphates have made very satisfactory growth.

Organic phosphorus in rice was found to be present in the form of phytin. Since the phytin occurs in unpolished rice and rice bran, but not in the polished rice, it is evident that the phytin is normally present only in the outer layers of the rice grain.

This station has been a persistent advocate of the use of legumes for green manuring for many years. Pot cultures have been made with 32 species of legumes. In one series of pots the entire plant has been turned under in order that the humus value and amount of nitrogen added may be determined. In the second series the nitrogen fixed by the plants has been determined. It was found that the nitrates in pots where legumes had been grown were much lower than in the check pot, but after removing the plant and allowing the pot to stand in the open the amount of nitrates soon equaled that in the check pots. Lime was found to be necessary for the best growth of the legumes.

Arsenite of soda has had quite an extensive use as a weed destroyer. In soil which had been sprayed with this chemical the arsenic was found to have accumulated in the top 4 inches of soil. The use of such sprays in excessive amounts should therefore be avoided.

The peculiar character of Hawaiian soils makes necessary some modifications of the ordinary methods of soil analysis. The experience in soil analysis on the part of the various chemists employed at this station has been summarized, and a modified method of analysis has been prepared and is given in the body of this report.

A bulletin of the station entitled "The Soils of the Hawaiian Islands"[1] gives the results of six years' work on Hawaiian soils, together with the practical application of the results obtained. Successful soil management requires deep plowing, followed by frequent shallow cultivations. Because of the heavy clay character of the soils and consequent danger of "puddling," the maintenance of the humus content by rotation of crops and green manuring is essential for the best results. Proper drainage is also important. In general, both nitrogen and phosphoric acid give good results as fertilizers. Soluble phosphates are recommended except in wet districts. Where there is a heavy rainfall the insoluble phosphates are best. Under similar conditions organic and ammoniacal nitrogen are better than the nitrate.

AGRONOMIC INVESTIGATIONS.

The principal crops experimented with during the year were rice, taro, corn, potatoes, cotton, millet, as well as various forage grasses and legumes. In a liming and fertilizer test the yield of shelled

[1] Hawaii Sta. Bul. 40 (1915).

corn was greatest on the plat receiving lime only, the same having been applied at the rate of 1,100 pounds per acre.

In an experiment to determine the effect of soil aeration on yields of rice it was found in the first experiment that 308 pounds more per acre was obtained from the aerated than from the nonaerated plat. The second test showed 680 pounds per acre in favor of aeration.

In a preliminary test for determining the effect of aeration on yields of taro the taro itself showed a slightly increased yield, while the "hulis" (offsets) showed a considerable increase on the aerated plat.

In a spraying test with Bordeaux mixture and lime sulphur for potato fungi on Early Rose potatoes the plat sprayed with Bordeaux produced at the rate of 30.2 bushels, as compared with 25.9 bushels for the lime-sulphur spray and 15 bushels per acre for the check.

In the tests of legumes for green manuring jack beans and velvet beans are among the most promising.

In an alfalfa yield test the ordinary alfalfas were found to outyield both the Peruvian and Turkestan varieties.

The sorghums constitute a very promising class of green forage crops, some averaging as high as 15 tons per acre, with the cutting 90 to 100 days apart.

Of the forage grasses Sudan grass is easily the most promising for general use throughout the islands. The fondness of the birds for seed of this grass makes the problem of seed production a difficult one. The station plats are protected with bird-proof nets.

Interesting results were obtained from Japanese millet. Yields as high as 12 tons of green forage, 3 tons of roughage, and 30 bushels of seed per acre have been obtained. Plantings of this crop are most satisfactory when made in November and December and harvested in January and February, the time of year when sorghums are not making rapid growth.

Numerous distributions of seed from all the more promising grasses and leguminous forage crops, as well as other field crops, have been made to farmers having facilities for making tests and increasing the available seed supply of the particular species in question.

AGRICULTURAL EXTENSION.

The extension division was definitely organized in November, 1914, although considerable extension work had been in progress before that date. The work centers in part in the substations referred to elsewhere in this report and in part in the various extension activities, such as demonstration farm work, trips to various stations on

the part of extension workers, assistance at agricultural fairs, fostering of boys' and girls' agricultural clubs, together with field demonstrations of improved means of crop production on private farms under the general supervision of the extension agents. It is felt that a great deal of good has been accomplished as a result of the voluminous correspondence with persons who have written to the station asking for advice and information concerning their more pressing agricultural problems. One of the most serious problems in connection with the extension work is that of providing for the large amount of travel that appears to be necessary if the agents are to keep in touch with the various individuals they should reach. Travel by water to a number of places is possible only by boats that make the call at rather infrequent intervals. On land the distances between the different sections are often such as to make automobile service essential in the interests of time economy. The commercial charges are such as to make it impossible to use such service except in cases of extreme emergency. It is true that a great many individuals have their own automobiles and willingly place them at the disposal of the extension agents for the visit to their places. Those who most need the services of the extension division, however, are seldom in a position to provide transportation of any kind.

SUBSTATIONS.

Owing to the withdrawal of Territorial funds, it was found necessary to abandon the various substations with the exception of that at Glenwood, which was continued on a greatly decreased allotment, a part of which came from private subscriptions. The banana work at Hilo, however, was continued under the supervision of the superintendent of the Glenwood substation. The extension funds of the station have made possible the employment of several collaborators who devote portions of their own farms to demonstration work and use the results obtained as a basis in part for extension work among the farmers they are able to reach. Work of this kind is under way at Haiku, Maui; at Hilo, Hawaii; at Kamuela, Hawaii; and at Kalaheo homestead, Kauai. At Hilo the collaborator is chiefly concerned with the development of improved methods of butter making in order that the product may compete more successfully with butter imported from the mainland. At Kamuela a typical homestead is being conducted by the collaborator at that place. He is making a number of trials of various crops to determine which are economically practicable under the local conditions. For instance, it is found that, while a considerable number of fresh green vegetables can be produced, it does not seem profitable to ship

them to Honolulu, owing to the long haul to the wharf, the high freight rate, and the rough treatment often accorded such shipments because of the necessity of transferring the shipments from small boats to the steamers, which are unable to reach the wharf. It therefore seems advisable for homesteaders in such sections to raise pigs and poultry and such crops as can be marketed in a dry condition and in quantity. At Kalaheo homestead the collaborator has given considerable attention to the extension of the poultry industry throughout his immediate section. He has also become interested in the possibilities of starch production from cassava, and a number of his neighbors are planting considerable acreages. At the present time the starch is selling for 7 cents a pound. At Haiku both extension work and demonstration work are under way on a comparatively large scale, and a separate report of the work of this station, as well as of that at Glenwood, appears in this report.

This station maintains what is essentially a substation on the slopes of Mount Tantalus at an elevation of about 1,000 feet. The station reservation includes all the land between the Tantalus substation and the station plats at the lower end of the tract, but most of the intervening land is uncleared and in this condition is not suitable for experimental work. At the upper station there are under test and observation numerous species of plants which do not thrive at lower altitudes. The principal crops under test are bananas, coffee, rubber, avocado, Chinese wood-oil nuts, Macadamia nuts, citrus trees, and roselle.

GLENWOOD SUBSTATION.

The reduction of the Territorial allotment for the work of the Glenwood substation materially handicapped the work of the station during the entire year, only the bare maintenance and a few other essential expenditures being possible. In spite of this handicap, which necessitated material curtailments in its activities, much good has resulted from the continued operation of the station. The dairy herds of the entire section have been improved by the utilization of the herd bull, while the sale of eggs for hatching from the station poultry flocks has materially improved many of the flocks throughout the islands. The introduction of such grasses as *Paspalum dilatatum* and the demonstration of the best methods of utilizing the native honohono have been of much assistance to the small farmer, who is largely dependent upon his herd of live stock for a livelihood. In addition to the actual work of the substation itself, the superintendent has taken an active interest in a large number of agricultural activities concerning which his advice and assistance were sought and apparently much appreciated.

NEEDS OF THE STATION.

There are several pressing needs of the station to which it is desired to call attention. At the station itself the services of a plant pathologist are needed. There are a number of plant diseases which manifestly lessen the production of several of the island crops which would otherwise be much more profitable. Among these may be mentioned potato blight, late blight of celery, a banana disease of somewhat obscure nature, a root rot of taro, and several other diseases which are not conspicuous simply because the crops which they attack are not at present being grown to any considerable extent on account of economic conditions prevailing in the islands. It is highly desirable that as complete information as possible be obtained concerning the best methods of controlling such plant diseases as now stand in the way of extensive production of the crops affected.

Hawaii presents, within limited areas, a greater diversity of climatic and soil conditions than can be found in an area of the same size in any part of the mainland of the United States. Within 3 or 4 miles the rainfall may vary from a few inches to 10 or 12 feet per year. The changes in altitude on the rapidly ascending mountain slopes cause changes in temperature varying from strictly tropical to that of the region of frost and snow. This great diversity gives rise to regional limitations of adaptability. Pineapples, for example, prosper at certain altitudes where there is sufficient rainfall. Coffee likewise flourishes at certain altitudes and under certain conditions of soil and rainfall, but elsewhere is a failure. Hence it becomes necessary that many of the problems pertaining to crop production be worked out in the localities typical for each crop. It is important that there should now be a pineapple substation where the problems of this industry, second only to sugar cane in value, might be worked out.

As another particular instance it may be mentioned that at Schofield Barracks there is a great need of forage for the Cavalry horses and work mules. At present hay has to be brought from the mainland at large expense for freight alone. There is available on the reservation probably sufficient ground to grow all the roughage required when once the proper varieties and cultural requirements have been determined. It has therefore been recommended that a local substation be established on the tract in question where the practicability of growing suitable grasses or other forage can be definitely determined.

It is therefore recommended that as fast as funds will permit there be established substations in the sections where crop problems are most pressing, and where the potential importance of the crops in question is sufficient to justify such an expenditure.

PUBLICATIONS.

During the year the following publications were issued by the station:

Annual Report for 1914.
Bulletin 35, Absorption of Fertilizer Salts by Hawaiian Soils.
Bulletin 36, Grasses and Forage Plants of Hawaii.
Bulletin 37, Ammonification and Nitrification in Hawaiian Soils.
Bulletin 38, Effect of Fertilizers on the Physical Properties of Hawaiian Soils.
Press Bulletin 47, Cold Storage for Tropical Fruits.
Press Bulletin 48, Suppression of Weeds Among Pineapples by Arsenite of Soda Spray.
Press Bulletin 49, A Cheap and Effective Home-made Plank Drag.
Press Bulletin 50, The Effect of Arsenite of Soda on the Soil.

REPORT OF THE HORTICULTURAL DEPARTMENT.

By J. Edgar Higgins.

The work of the horticultural department has been continued along lines similar to those of recent years. During the first part of the year the horticulturist was absent from the office, having reported for duty in Porto Rico at the close of a year's leave of absence. The latter part of June of the last fiscal year was spent in investigations of the fruit industries of Porto Rico, and the early part of the present fiscal year in travel in Cuba and Florida. The purposes of this travel were to observe horticultural conditions and progress in the countries visited with a view to the improvement of horticultural practices in Hawaii. The results of these investigations have been prepared for presentation in a separate report (see p. 58).

THE EXTENSION OF THE LITCHI.

The litchi, *Litchi chinensis* (*Nephelium litchi*), is now attracting considerable attention, not only in Hawaii (see Pl. I, fig. 1), but also in Florida and southern California. It appears probable that this fruit tree is adapted to a wider range of conditions than has been supposed. The excellence of the fruit and its very high price in Honolulu (60 to 75 cents a pound), due to the limited supply, makes it worthy of more attention. Considerable data have been accumulated during the year on methods of propagation, preservation of seeds, fruiting age, cultural methods, etc., which are being brought together in a separate paper. This station is cooperating in experiments in Florida and California with this species. A large number of seeds has been shipped to Florida in the pursuit of this work, and also as an experiment in transporting these short-lived seeds. About 50 pounds of fruit was shipped to the Office of Foreign Seed and Plant Introduction, in Washington, D. C., as a further means of testing the possibilities of the shipment of seeds and fruits. The shipment went in refrigeration as far as San Francisco and thence by ordinary express, icing being impossible with so small a quantity. The fruits are reported to have arrived in good condition.

On July 5 another small lot of fruit was placed in the fruit room of the United States Army transport *Thomas* at Honolulu en route for San Francisco. These were removed from refrigeration by the writer before arrival in San Francisco. They were in perfect pres-

ervation, apparently having lost nothing in flavor and appearance. Part of the seed was sent by mail in moist sphagnum moss to Washington, D. C., and part was distributed in localities of California, where it is hoped this species may succeed. All of this seed germinated well, demonstrating that it was not injured by refrigeration, and, further, that this is one of the means by which litchi seeds may be transported where refrigeration for fruit is available.

THE MANGO.

A number of interesting facts have been observed in the mango studies. Some preliminary studies have been made on the flowers of certain varieties and on methods of pollination. In the Alphonse variety, for example, it was found that a very large proportion of the flowers of the lower (inner) portion of the cluster was staminate. These staminate flowers have but one fertile stamen and four staminodes. They are unisexual by the abortion of the pistil, which sometimes may be detected in its aborted condition. These staminate flowers, while most abundant in the lower part of the lateral clusters, are also found throughout the entire cluster except near the outermost end of the central axis. The hermaphrodite or perfect flowers are found in all parts of the cluster, but chiefly near the termination of the lateral branches and of the central axis. At the base of the lateral clusters there are very few. These hermaphrodite flowers have but one stamen and one pistil, with four staminodes. The pistil is without any marked enlargement at the stigma.

The pollen of all the varieties of mango studied was found to be very small and almost colorless. In the few cross-pollinations which were made the ruptured anthers were brought into immediate contact with the flower being used as the female parent. This appeared to be a more practical means than any attempt to gather minute pollen grains and apply them with a brush.

PREMATURE FLOWERING.

Several mango seedlings less than 9 months old which had been grafted by inarching were found to be producing flower clusters above the point of union. In most cases the scion also was flowering, but in one case only the seedling stock. The mango tree ordinarily does not flower until it is from 5 to 6 years old, and the flowering of young seedlings less than a year old is quite beyond any observations that have been made here, and, so far as the writer is aware, no such cases have been previously recorded. Of 27 seedlings grafted to the Pirie, 4 produced flower clusters on the scions only, and 5 produced flowers on both seedlings and scions; of 5 grafted to the variety Brindabani, 1 produced flowers on the scion and on the seedling

stock, and 1 produced flowers on the seedling stock only, with none on the scion. That is to say, 18 per cent of the plants grafted to Pirie and 20 per cent of those grafted to Brindabani formed flowers on both scions and stock. There is, of course, nothing remarkable in the production of flowers on the scions. It is very common to find scions producing flowers from flower buds which have been matured on the tree before the removal of the scion, but flowers on seedling mango stocks less than 1 year old are worthy of note.

No cause can be ascribed for these phenomena except the grafting. It is true that the seedlings had been cut back slightly to induce growth in the scion, but this injury to the top of seedlings frequently occurs. Possibly the unusual results may be accounted for by the influence of the scion upon the stock, and it will be noted that in all cases save one the scions flowered as well as the stocks. In this one exception, the scion showed the scar of a flower cluster of the last season at its terminus. The mere mechanical injury brought about by grafting and the constriction resulting from the tightening of the raffia bands should also be taken into consideration. Plate I, figure 2, shows some of the trees referred to bearing their flowers.

BUD MUTATION.

Instances of bud mutation have not been commonly reported in the case of the mango. An instance apparently illustrating this phenomenon has recently received attention. Several trees grown from seed of the variety locally known as No. 9 have all produced fruits of the general type. A single branch of one of these trees, however, produced a pink fruit (the No. 9 is green), rather smaller in size than the regular type, but otherwise resembling the variety from which it was grown.

BARK GRAFTING.

The bark grafting of the mango, which has been successfully applied by the Porto Rico Experiment Station, has been tested under Hawaiian conditions during the year. It has proved to be well adapted to the work of top-grafting established trees and is one more method available in this work. One of the great advantages of the method is its extreme simplicity. Bark grafting, which has been so commonly used in Hawaii on hibiscus, consists in the cutting of a scion with one bearing surface and inserting the same under the bark of a branch which has been cut back for the purpose (Pl. II, fig. 1). Branches of the stock may be selected from 1 inch to 3 or 4 inches in diameter, at a time when the bark is slipping. This feature is extremely important, as it is also when budding the mango. This condition of the bark usually occurs when the terminal buds

are just beginning to burst open. A single straight slit about 5 inches long is made in the bark where the branch is cut off. The best scions are of rather small, well-matured wood of the last flush, and the end of the flush is preferable. Such scions are cut with one straight cut, giving a single bearing surface to be placed next to the cambium of the stock. The scion must then be securely tied in place with a strong tie, because the mango bark is thick, and if it begins to dry out it will break a weak strand. The whole scion and the top of the branch used as a stock must then be covered with a paper sack which has been dipped in warm wax. The sack is then tied close to the stock. This covering prevents excessive transpiration of moisture from the scion, which otherwise would be exhausted before a union could take place. The covering may be removed in about three weeks. From 50 to 75 per cent of the scions so inserted, under favorable conditions, may be expected to grow.

With this method available, as well as others which have been described in earlier reports and bulletins, there certainly is no good reason for continuing to allow vigorous trees to produce the worthless fruits which many now yield. The common Hawaiian mango is so inferior to some of the newer varieties that for this reason alone it should be largely replaced. The fact that the Hawaiian variety is so extremely subject to attacks of the Mediterranean fruit fly that few fruits escape, is a further reason for reducing the number of this variety and substituting the Pirie or other resistant varieties.

THE AVOCADO.

The avocado is one of the few fruits that is attacked by the fruit fly to so slight a degree that the injury is practically negligible from the standpoint of fruit production, although the pest has interfered with the marketing of this fruit on the mainland of the United States. Hawaii, however, has been of assistance to the mainland in the establishment of the avocado industry there, the results of most experimental work in Hawaii being of use in Florida and southern California. Many of the Hawaiian seedlings suffered severely in the frost of southern California in the winter of 1913. Some, however, the Nutmeg, for example, have shown considerable resistance to cold. Among the Hawaiian seedlings which are attracting attention in California are the Solano and the Meserve.

The Macdonald, the parent tree of many of the round, hard-shelled winter seedlings, has attracted some attention this year by its remarkable keeping qualities. Fruits were kept in the horticultural laboratory for 16 days without any refrigeration, and at the end of this time were in a perfect state of preservation. These winter fruits are most promising because of their season, and the hard-shelled character is greatly in their favor.

PROPAGATION EXPERIMENTS.

The method of bark grafting applied to the mango has also been tested on the avocado, but has not, up to the present time, proved satisfactory. Scion budding, however, which is quite similar in character, has given satisfactory results. This consists in inserting a scion in a T-shaped incision in the stock. The stocks used for this purpose have been from 1 inch to 4 inches in diameter. The T-shaped incision is made in the same manner as for shield budding, but is much larger. The scion consists preferably of a short piece at the end of a branch from a mature tree which is not growing too rapidly (Pl. II, fig. 2). This scion is prepared by a single cut, and is inserted in the incision, bringing one surface only into contact with the cambium of the stock. It is then tied in place and waxed with a firm grafting wax which will not run when heated by the sun.

This method of propagation appears to have two points in its favor. It affords a means of propagating from old bearing trees which frequently do not produce good bud wood unless they are severely cut back and forced to do so. Scions, however, may be taken from the terminals of slow-growing branches on which there is no material for ordinary shield budding. A further point in favor of the method is that it can be used to work into branches of considerable size, whereas for shield budding it would be necessary to cut back the stock and await the growth of new shoots in which to insert the buds. It is not intended to imply that this method is preferable to shield budding even for top-working trees, but that it may be rendered serviceable under certain conditions.

MULTIPLE-STEMMED SEEDLINGS.

It is a well-known fact that many avocado seeds send up numerous stems. It has been suggested that some of these might be the result of multiple germs. All the multiple-stemmed seedlings which have been studied up to the present time have indicated that there has been a single central stem and the others have arisen from buds on this stem beneath the surface of the ground and in many cases within the seed.

THE PAPAYA.

The work of the breeding of papayas was resumed along the lines indicated in earlier annual reports and in a bulletin of the station.[1] There are no conclusions of special moment to report at present. A number of crosses and close pollinations have been made to secure information on questions arising in earlier work. It is very interesting as well from a practical as from a scientific point of view to

[1] Hawaii Sta. Bul. 32 (1914).

FIG. 1.—HONOLULU'S OLDEST LITCHI TREE.

FIG. 2.—MANGO SEEDLINGS IN FLOWER, LESS THAN 9 MONTHS OLD.

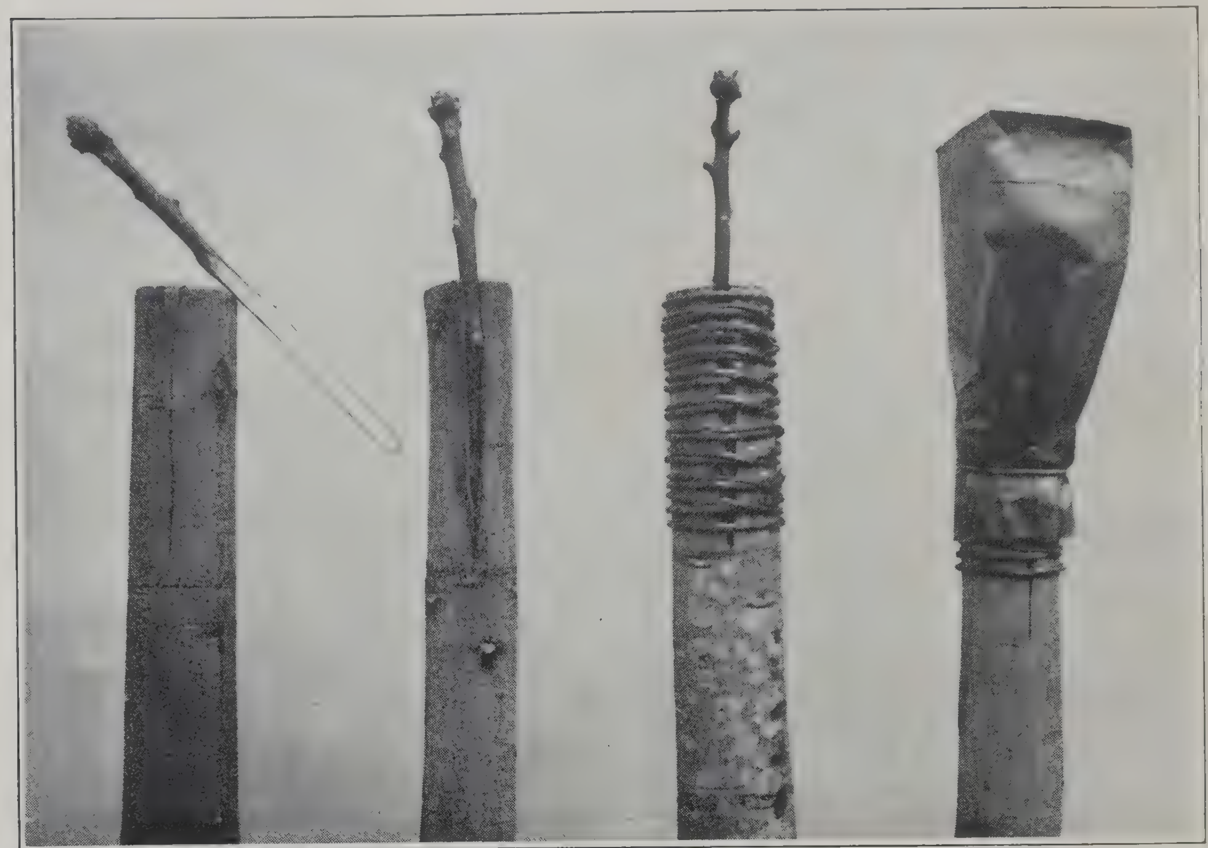

FIG. 1.—BARK GRAFTING THE MANGO.

FIG. 2.—SCION BUDDING APPLIED TO THE AVOCADO.

learn what are some of the factors determining sex in a species producing both diœcious and hermaphroditic stocks. Will the pollen from a hermaphrodite flower produce offspring that will be almost exclusively fruit bearing, either pistillate or hermaphrodite? To throw light on this and related questions, pollinations have been made as follows:

Flowers of pistillate trees of diœcious stocks have been fertilized with pollen from hermaphrodite flowers of the elongata form. Flowers of pistillate trees of the hermaphroditic stock have received pollen from staminate trees. Pistillate trees of diœcious stocks again have been fertilized with pollen from hermaphrodite flowers of the pentandria forms, both oval and pyriform. The possibility of perfecting such fertilizations had in most cases been determined in earlier experiments, but the sex of the progeny has not yet been observed.

A series of close pollinations also has been begun, wherein hermaphrodite flowers of elongata form have received their own pollen exclusively, the purpose being to initiate close breeding.

A number of cross-pollinations also has been made with a view to determining, if possible, and combining unit characters pertaining to flavor, keeping qualities, uniformity in shape, and bearing habits.

CITRUS ORCHARD.

In the citrus orchard many varieties are now in bearing and making a satisfactory growth. Practically all these varieties have been introduced as bud wood and have been worked upon home-grown stocks, thus building up a supply of all the leading varieties of orange, lemon, lime, and grapefruit. A limited amount of bud wood of the following varieties, now bearing, is available: Oranges—Bahia, Bouquet des Fleurs, Golden Buckeye, Golden Nugget, Mediterranean Sweet, Navelencia, Ruby, Scented, Thompson, Valencia, Dancy, King, Willowleaved, and Satsuma; pomelos—Duncan, Imperial, Marsh, McCarty, Royal, and Triumph; lemons—Eureka, Genoa, Lisbon, Ponderosa, and Villafranca; and limes—Kusaie and Tahiti.

WOOD OIL AND KUKUI.

The commercial possibilities of the oil of kukui, *Aleurites moluccana* (*A. triloba*), and of the China wood oil, *Aleurites fordii* (*A. cordata*), have recently attracted considerable attention. It is claimed by some manufacturers that a blend of these two oils is preferable to either. It has been suggested that the hybridizing of these species might result in new forms that might combine the desired characters in a way superior to either of the parents. In bear-

ing habits the China wood-oil tree appears to be quite inferior to the kukui, which bears in clusters, while the Chinese tree produces usually only one nut at the end of each branch, where there is ordinarily found one pistillate flower surrounded by several staminate flowers.

Mr. Valentine S. Holt, assistant horticulturist, was requested to attempt the hybridizing of these species. From 37 cross-pollinations, in which *A. fordii* was used as the female parent, 26 fruits are now set. On *A. moluccana* there are 94 fruits, the flowers of which received pollen from *A. fordii* only. In neither case has it yet been proved that parthenocarpic or parthenogenetic development does not occur in these species, but it appears probable that there is an affinity between them which may be ultilized in hybridization.

DISTRIBUTION OF SEEDS AND PLANTS.

A large number of valuable grafted and budded fruit trees have been distributed to different parts of the Territory, and some have been sent to the mainland and to foreign countries. These have consisted chiefly of mango and avocado, with a few lemons, limes, oranges, and grapefruit. Except in case of exchange, it has been the custom to make a charge for these to cover in part the cost of propagation and handling. By reason of a recent act of Congress, all money now received from sales of products reverts to the Treasury of the United States and does not become available for the use of the experiment station. It thus becomes impossible to recover expenditures made in propagation. For this reason and because other funds are not available, it will be necessary largely to discontinue this work, except as it relates to the introduction and establishing of new and unusual varieties.

The same applies even more strongly to the distribution of hibiscus cuttings. The new varieties of these ornamentals which have been originated here have been distributed in numbers aggregating hundreds of thousands at a nominal charge and may now be seen in all parts of the Territory, while they add to the beauty of many tropical lands. These flowers of rare and delicate beauty will be an asset to the Territory far exceeding all that they have cost. The time has come, however, when the future distribution of the plants and cuttings should be put on a commercial basis.

It has become necessary greatly to reduce the number of hibiscus plants at the experiment station, the land, and more particularly the water, being required for other plants. One plant of each of about 500 or 600 varieties, however, will be retained, while the others will be placed along the public highway at Army posts and public parks where they will benefit the largest number of observers.

Papaya seeds of the varieties bred here have been distributed to a large number of applicants. This will be continued in conjunction with the breeding work.

Seeds of various other economic plants have been distributed, among which may be mentioned roselle, *Carissa grandiflora*, Annonas, Carambolas, and star apples.

Bud wood of citrus varieties has also been sent wherever it has been requested.

EXTENSION WORK IN HORTICULTURE.

The knowledge of budding and grafting is not so general here as in countries where there is large commercial orcharding. Through various methods of extension work, the art is being taught which will make of more service the large collection of varieties at the station. Assistance was given by instruction and demonstration at the summer school for teachers. A trip was made by the horticulturist to the island of Maui, chiefly in the interest of this work. Another trip was made to Hilo to assist in the county fair. The horticulturist is now acting in an advisory capacity in connection with the present effort of the Territorial marketing division to place Hawaiian pineapples in the mainland markets in much larger quantities than heretofore, and thus relieve the situation of the growers who are unable to dispose of their crop.

NEEDS OF THE HORTICULTURAL DEPARTMENT.

The greatest needs of the horticultural department of this station at present are land and other facilities for culture experiments with pineapples and bananas. These are the two fruits of commercial importance for export, and at present they are the only fruits that are allowed entrance from Hawaii to the mainland markets. There is great need for field experiments with both of these crops, but none of the land at the experiment station furnishes normal conditions for them. It is hoped that funds may be made available for the leasing of a suitable tract of land upon which to begin this work.

REPORT OF THE ENTOMOLOGICAL DEPARTMENT.

By D. T. Fullaway.

The entomologist of the station was absent on leave from July 1, 1914, to May 31, 1915. During this time he was in the employ of the Territorial Board of Agriculture and Forestry, being engaged in the prosecution of the general campaign development of parasites of the Mediterranean fruit fly, a work which has met with considerable success.

The close proximity of these two stations to one another made it possible for the entomologist to keep his office open at the Federal experiment station and to attend to his routine work of correspondence and maintenance of the insect collection, which was greatly increased by material obtained from abroad.

During the month of June, 1915, most of the entomologist's time was spent in studies in connection with *Sierola* spp., the natural parasites of various species of Lepidoptera.

While the repeated absences of the entomologist from the station in connection with the Territory-wide insect parasite campaign has to some extent interfered with the work of independent investigation, it is believed, however, in view of what has been accomplished, that the agricultural interests of the islands have been better served than they would have been had the entomologist remained at the station engaged in individual work with parasites of the insect enemies of the agricultural and horticultural crops, or in other lines of entomological activity.

REPORT OF THE CHEMICAL DEPARTMENT.

By Wm. T. McGeorge.

During the past fiscal year Dr. W. P. Kelley resigned as head of the department to become professor of agricultural chemistry at the Graduate School of Tropical Agriculture and Citrus Experiment Station at Riverside, Cal. The work of the chemical department has proceeded with little interruption along the same lines as outlined in previous reports.

The investigation of scientific soil problems, having a very practical significance in the islands, has received the continuous attention of the staff, while all miscellaneous routine analyses have been made with as little interruption of the above work as possible. Marked progress has been made toward a thorough understanding of the peculiar properties, both physical and chemical, of Hawaiian soils.

FIXATION OF FERTILIZERS.

During the fiscal year 1914 experiments on the fixing power of Hawaiian soils were completed, and the results were issued during the past year as a bulletin of the station.[1]

Due to the highly basic character of these island soils, the fixation of phosphoric acid is much higher than that of the other elements. The results show that the best method of application of the phosphates is just before planting. The soluble form should ordinarily be used.

The fixation of potash is apparently controlled by the amounts of lime and magnesia present, and is quite marked. Some loss by leaching is possible, however, if the potash is applied in too large quantities.

With ammonia nitrogen, while the point of saturation is higher, the fixation is not so strong as that of potash. Soils rich in humus retain the ammonia and also the potash better than the red clay type. This is probably due to interaction with the complex "humates."

The Hawaiian soils retain little, if any, of the nitrogen in the form of nitrate. Some highly organic soils, however, react with and fix some of the nitrate solution. Air drying, heat, and the use of antiseptics have little influence on the fixing power of the soil.

[1] Hawaii Sta. Bul. 35.

BACTERIOLOGICAL INVESTIGATIONS.

The results obtained by Dr. Kelley in the study of bacterial action in Hawaiian soils were published during the year as a bulletin of the station.[1]

Due to the unusual character of the Hawaiian soils, the decomposition of organic nitrogen compounds into forms available for plant food is of considerable importance. The lime-magnesia ratio as influencing nitrification being a subject of much controversy, an investigation was made of the effect of magnesia on nitrification.

Observations show that nitrification does not take place in most Hawaiian soils unless oxidizing conditions are maintained by tillage. Besides aeration, virgin soils also require weathering for several months before the nitrifying bacteria will become active.

The effect of heat and antiseptics was also investigated. Partial sterilization probably makes available, through alterations in the colloidal film, new stores of food and organic material to the surviving organisms, and thus stimulates bacterial action. The effect of aeration also is partly due to the same cause assisted by granulation and oxidation.

The lime-magnesia ratio does not seem to be of much importance in Hawaiian soils. Magnesium carbonate favored ammonification, while calcium carbonate stimulated nitrification in some instances. Dolomitic and calcareous limestone will probably produce similar effects on the availability of the nitrogen in Hawaiian soils.

For any system of permanent agriculture on Hawaiian soils, rotation of crops, including green manuring, must be strongly insisted upon in order to maintain the best aeration possible.

PHYSICAL STUDIES OF HAWAIIAN SOILS.

In another bulletin issued during the year,[2] the results are given of an extensive study of the physical properties of Hawaiian soils and the effect of fertilizers on these properties. Since it is impossible to measure by chemical analysis the presence of a normal application of fertilizer in the soil, and since it has been shown that the addition of salts and fertilizing materials affects the structure of the soil materially, it is suggested that these measurements of the physical effects of applications of fertilizer would be of considerable importance in determining the value of the fertilizer salts.

In most instances the fertilizer salts increase hygroscopic moisture, lower vapor pressure, and increase the cohesion of the soil particles. Capillarity is diminished in clay soils but increased in sandy soils by the addition of salts. Fertilizers increase the resistance to percolation, which takes place most rapidly in sandy soils.

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[1] Hawaii Sta. Bul. 37. [2] Hawaii Sta. Bul. 38.

SOIL SURVEY.

Previous to the resignation of Dr. Kelley, a paper entitled "The Soils of the Hawaiian Islands" was prepared and submitted for publication as a bulletin of the station.[1] In this bulletin the work of about six years' investigation upon Hawaiian soils is taken up, dealing with the composition of the various types of soil found on the islands and the practical bearing and application of the various scientific investigations which have been carried on in this laboratory.

THE ORGANIC PHOSPHORIC ACID OF RICE.

It has been known for some years that phosphoric acid exists in grains in organic combination with inosite and some base, and, as such, is taken into the animal system as a supply of phosphoric acid to the body. Because of its physiological value, the organic phosphoric acid which is known as phytin or phytic acid has received considerable attention, and a number of investigators have studied its composition and occurrence in grains.

It was believed that a study of phytin in rice would be of interest, since rice is one of the principal crops raised in Hawaii, and is valued as food by many of the inhabitants. The isolation and study of the composition of the phytin in rice was made by Miss Alice R. Thompson, assistant chemist, and the detailed results have been published elsewhere.[2] It was found that most of the phytin in rice exists in the outer layer of the grains, and in the process of polishing the rice practically all the phytin is removed. Phytin was isolated from unpolished rice and from bran, but none could be obtained from polished rice. The total phosphorus was determined in the samples and found to be 2.29 per cent in the rice bran, 0.321 per cent in unpolished rice, and 0.140 per cent in polished rice.

The phytin was obtained by treating the sample bran and unpolished rice with 0.2 per cent hydrochloric acid and precipitating with barium hydroxid. The white barium salt was washed, dissolved, and reprecipitated several times with barium chlorid and alcohol. The composition of two samples of the tribarium salt was determined and the barium, phosphorus, carbon, and hydrogen contents compared with that of the tribarium-inosite-hexaphosphate salt reported by Anderson in other grains.

Special attention was paid to several methods of determining barium in the salt, and precautions were noted to be observed in obtaining a pure barium sulphate precipitate from solutions of the salt.

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[1] Hawaii Sta. Bul. 40 (1915).

[2] U. S. Dept. Agr., Jour. Agr. Research, 3 (1915), No. 5, pp. 425–430.

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Inosite was insolated from the barium phytate and its melting point determined.

THE EFFECT OF ARSENITE OF SODA ON THE SOIL.

The increased use of arsenite of soda spray as a means of killing weeds led to a study of the injurious effect of this chemical. Attention was given to its influence upon plant growth, on the biological and physical properties of the soil, and its chemical action toward the soil constituents. The soils studied were found to have a very strong fixing power for arsenic. A sample of soil from Nahiku, Maui, on which weeds had been sprayed for five years at the rate of three sprayings per year (5 pounds arsenic per acre per application) showed on analysis that all the arsenic was held in the top 4 inches of soil. Accounts of this work have been published.[1]

THE AVAILABILITY OF PHOSPHATES.

This work, also mentioned in the last annual report, has been completed and submitted for publication as a bulletin of this station. It was broadened considerably more than was at first anticipated in order to study phosphates more thoroughly from all angles. The availability of all the commercial phosphates was compared; the solubility of phosphates naturally occurring in Hawaiian soils was studied; the fixation of phosphoric acid by the soil received some attention; and, finally, as an appendix, a modified method for determining phosphoric acid in local soils was submitted. The latter method was adopted after nearly 250 phosphate determinations.

The importance of the above work is realized when it is known that the phosphate content of Hawaiian soils is, with rare exceptions, ample for good plant growth, but owing to its extremely unavailable condition the addition of this type of plant food as a fertilizer is often desirable.

LEGUMES AS GREEN MANURE.

This station has consistently advocated the use of legumes as a green manure. The benefit derived from legumes is due to both chemical and physical effects on the soil; the nitrogen content is increased and the texture of the soil is improved by the added humus. The red clay Hawaiian soils, especially, need green manure to prevent puddling and to aid aeration.

In order to determine the relative value of the various legumes, pot experiments were made by Miss Alice R. Thompson, assistant

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[1] Hawaii Sta. Press Bul. 50 (1915); U. S. Dept. Agr., Jour. Agr. Research, 5 (1915), No. 11, 459–463.

chemist. One hundred and thirty-two pots were filled with a calcareous soil and the same number with a lime-poor soil. Thirty-two varieties of legumes were grown, one variety being apportioned to four pots of each soil type. Four pots of each soil were thus left as checks. At maturity the duplicate plants in two of the four pots were removed, weighed, and the nitrogen determined. Nitrates, nitrites, ammonia, and total nitrogen were determined in the soil and compared with the check pots, after deducting the nitrogen added in the legume seed. Two pots were left of each variety of legume planted, the plants being turned under to decompose. The quantity of nitrogen added to the soil will be determined later.

In all instances the nitrates in the soil from which the legumes had been removed was much lower than in the check soil. But these soils low in nitrates on standing in the open air soon equaled in nitrate value the soil of the check pots. Where much legume material was turned under the nitrates in the soils were greatly increased.

The plants grown in soils deficient in lime made a poor growth and had a lower nitrogen content, calculated on a water-free basis, than the plants grown in soils rich in lime. In a second experiment lime was added to the lime-poor soil, but the plants grown in this soil were also undersized and low in nitrogen. In a third experiment phosphate fertilizer was added to the lime soil and plants again grown in these pots. Results are to be obtained in a few months from the last series.

THE ANALYSIS OF HAWAIIAN SOILS.

In the course of the examination of about 600 soil samples in this laboratory peculiarities in soil types have been met which necessitated slight modification in the method of soil analysis as outlined by the Association of Official Agricultural Chemists. Chief among the inhibiting factors may be mentioned the high content of iron, aluminum, titanium, and manganese.

The modifications found to produce best results are submitted herewith, as are also some data showing the influence of time upon the solvent properties of hydrochloric acid. It was hoped that, in view of the low silica content, the time of digestion could be shortened to advantage without lowering the thoroughness of the extraction.

Four soils were chosen for this work—a sandy soil (No. 1), a red clay (No. 2), a silty soil of high humus content (No. 3), and a brown clay (No. 4). These soils were digested on the steam bath with hydrochloric acid (specific gravity, 1.115) for 1, 4, 6, 8, 10, and 15 hour periods. The results are given in the table following.

Effect of time of digestion of soil in hydrochloric acid (specific gravity, 1.115) on thoroughness of extraction.

Soil No.	Time.	Insoluble residue.	Iron oxid.	Alumina.	Titanic oxid.	Mangano-manganic-oxid.	Lime.	Magnesium oxid.	Potash.	Sulphur trioxid.	Phosphoric acid.
	Hrs.	*Per ct.*	*Per ct.*	*Per ct.*	*Per ct.*	*Per ct.*	*Per ct.*	*Per ct.*	*Per ct.*	*Per ct.*	*Per ct.*
1	1	45.30	15.04	9.64	1.36	0.22	3.39	8.74	0.19	0.26	1.09
	4	48.12	16.44	9.21	1.41	.30	3.09	....	.58	.21	.90
	6	38.06	16.36	14.79	1.61	.17	3.09	10.60	.62	.22	1.05
	8	37.10	16.80	14.44	1.71	.23	3.27	11.50	.72	.25	.96
	10	37.98	16.94	13.53	1.76	.17	3.58	10.50	.82	.35	.99
	15	37.61	17.80	13.33	1.76	.18	3.21	11.10	.75	.32	.99
3	1	37.24	9.08	10.90	1.07	.12	3.52	.91	.62	.35	2.35
	4	34.83	9.20	13.89	1.07	.11	4.00	1.02	.45	.34	2.31
	6	34.41	9.72	14.51	1.12	.12	3.76	.97	.41	.32	2.28
	8	34.15	9.44	14.91	1.12	.12	3.69	1.03	.52	.38	2.39
	10	34.30	9.88	14.73	1.12	.20	4.14	1.11	.58	.35	2.29
	15	34.38	9.72	14.55	1.07	.13	3.90	1.02	.59	.38	2.26
2	1	45.05	14.92	12.35	.78	3.03	.52	.28	....	.26	.27
	4	35.58	16.16	20.83	.97	2.81	.54	.32	.26	.27	.37
	6	32.90	15.36	24.03	1.02	2.89	.52	.34	.38	.23	.32
	8	31.38	16.08	25.25	1.02	2.48	.58	.58	.44	.26	.44
	10	30.89	16.52	25.94	1.07	2.53	.65	.57	.43	.29	.42
	15	29.93	17.40	25.01	1.07	2.63	.63	.59	.53	.28	.50
4	1	46.10	24.64	10.67	3.12	.04	.26	.74	.11	.19	.53
	4	38.77	29.92	11.48	3.90	.04	.30	1.05	.16	.22	.43
	6	34.59	30.00	11.96	4.19	.04	.30	.94	.20	.21	.40
	8	35.89	32.64	11.72	4.19	.07	.42	1.23	.23	.24	.36
	10	35.88	30.44	13.34	4.19	.08	.36	1.21	.22	.22	.50
	15	35.05	31.60	13.07	4.19	.04	.41	1.30	.26	.26	.51

As previously mentioned, it was hoped that a reduction in the time of digestion could be made for local conditions, but apparently best results are obtained by digesting for 10 hours. However, the conclusion is plainly evident that the use of hydrochloric acid of this strength is primarily a study of solution and not of ultimate composition, when applied to Hawaiian soils. A digestion of 10 hours by no means results in a complete extraction in all soils.

MODIFICATION IN ANALYSIS.

ACID DIGESTION.

Digest 10 grams of soil for 10 hours in a 300-cubic centimeter soil digestion flask with 100 cubic centimeters of hydrochloric acid (specific gravity, 1.115) in boiling water. Dilute with 50 cubic centimeters of water, filter while hot into a 500 cubic centimeter volumetric flask, and wash the residue until the filtrate is nearly 500 cubic centimeters. Cool to room temperature and make to volume (solution A).

INSOLUBLE RESIDUE.

Dry the insoluble residue and ignite to constant weight.

IRON, ALUMINUM, AND TITANIUM.

Take 50 cubic centimeters of solution A, add a few drops of nitric acid, boil for a few minutes, remove from hot plate, make

slightly alkaline with ammonia, and boil off the excess. Filter, wash several times with hot water, and transfer the precipitate and filter to the original beaker. Dissolve by boiling in dilute hydrochloric acid. Reprecipitate as before, filter, and wash free of chlorid. Dry, ignite, and weigh the precipitate as ferric oxid, alumina, titanium oxid, and phosphorus pentoxid. Reserve the filtrate (solution B) for determining manganese, calcium, and magnesium.

Treat a second aliquot of 50 cubic centimeters of solution A in the same way up to the point of ignition of the ammonia precipitate. Instead of igniting, transfer the precipitate to the original beaker and dissolve by boiling in dilute sulphuric acid. Transfer to a 100-cubic centimeter volumetric flask, cool, and make to volume. Determine the iron by titrating 25 cubic centimeters of this solution with tenth-normal potassium permanganate in the regular way. Determine titanium by the colorimetric method as follows: Transfer 5 cubic centimeters of the sulphuric-acid solution to a 50-cubic centimeter Nessler tube, dilute, and add 5 cubic centimeters of dilute sulphuric acid, 5 cubic centimeters of hydrogen peroxid, mix well, and compare with a standard prepared at the same time from a solution of titanium sulphate. The filtrate from the second aliquot should be reserved for the determination of sulphate, soda, and potash (solution C).

Since potassium permanganate oxidizes titanium as well as ferrous iron, it is necessary to calculate the volume of permanganate required to oxidize the titanium present and to make a correction accordingly in calculating the iron. The aluminum is determined as usual by difference.

MANGANESE.

Concentrate solution B to about 150 cubic centimeters, add about 3 cubic centimeters bromin (undiluted), allow to stand 5 minutes, add an excess of ammonium hydrate, and heat to boiling. Let stand overnight, filter, wash with hot water, dry, ignite, and weigh as mangano-manganic oxid (Mn_3O_4).

CALCIUM.

Evaporate the filtrate to dryness and drive off the ammonium salts. Dissolve the residue in dilute hydrochloric acid and determine calcium in the regular way. The removal of the large excess of ammonium salts is necessary in order that any unprecipitated manganese will be thrown down.

MAGNESIUM.

Magnesium may be determined by precipitation in the regular way from the above filtrate direct.

SULPHATES.

Best results have been obtained by removing the iron and aluminum previous to the precipitation of the sulphate. Hence, solution C is evaporated to dryness, ammonium salts volatilized, the residue dissolved in dilute hydrochloric acid, and the sulphate determined in the regular way with barium chlorid.

POTASH AND SODA.

From this point the analysis may be carried out on the above filtrate according to the official methods without modification.

PHOSPHORIC ACID.

To 50 cubic centimeters of solution A add a few drops of nitric acid and heat to boiling. Make alkaline with ammonium hydrate, boil off excess, filter, and wash. Transfer filter and contents to a beaker and boil with dilute nitric acid, nearly neutralize with ammonia, add 50 cubic centimeters of molybdate mixture with constant stirring, and allow to stand in water bath for four hours at 55° C. From this point proceed as in the official method.

HUMUS.

Modifications in the method of determining humus are dealt with in full in a press bulletin of this station.[1]

SOIL COLLOIDS.

Frequent mention has been made in previous publications of this station of the presence of colloids in Hawaiian soils. A condition which apparently arises through the formation of this class of bodies was given some attention during the past year.

The clay soils may be divided into two classes: Class 1, in which the alumina is higher than the iron and the titanium is very low; and class 2, in which the alumina is lower than the iron and the titanium is high. The former class is the one showing the more colloidal properties, and in spite of this contains fewer clay particles than the latter class. In the analysis of the hydrochloric-acid extract, considerable difficulty arises upon filtering the ammonia precipitate of iron, aluminum, and titanic hydrates and phosphates. The inhibiting factor presents itself in the form of a colloidal gel, rendering the washing of the ammonia precipitate extremely difficult. This gel is insoluble in cold acids, and hence in redissolving the precipitate it is necessary to boil it in an acid solution.

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[1] Hawaii Sta. Press Bul. 33.

A sample of this colloidal gel was analyzed with the following results:

	Per cent.
Silica (SiO_2)	1.04
Phosphoric acid (P_2O_5)	1.02
Manganomanganic oxid (Mn_3O_4)	.73
Titanic oxid (TiO_2)	.66
Ferric oxid (Fe_2O_3)	9.37
Aluminum oxid (Al_2O_3)	87.18

Apparently this colloid is aluminum hydroxid, the physical properties of which are influenced by a small amount of silica and titanium. In all soils which contain iron in excess of alumina, this colloidal gel is never formed, but in soils of high aluminum content it is invariably present.

THE EFFECT OF PARTIAL STERILIZATION ON PLANT GROWTH.

Considerable study has been devoted to the effect of partial sterilization upon Hawaiian soils. A previous publication[1] treats of the effect of heat upon the physical and chemical properties of the soil, while the biological influences are thoroughly dealt with in the bulletin referred to on page 30.

During the year the above work has been supplemented by pot experiments. Heretofore the influence of sterilization on plant growth has been demonstrated in an experimental way in Hawaii only in districts where brush, accumulated in clearing land, has been burned upon the soil. In these cases a remarkable influence upon plant growth has been noted.

The pot experiments were carried out as follows: Two types of soil were used, a red clay and a sandy soil high in organic matter. These soils were treated as follows: Heated in sunlight, in an oven at 80°, 110°, and 165° C., and in an autoclave at 10 pounds pressure. Those heated in the oven were left for 2 hours, that in the autoclave for only 1 hour. In addition soils were treated with the following antiseptics at the rate of 10 cubic centimeters per kilogram: Carbon bisulphid, chloroform, and toluene. Also a check was run with the above in which the soil fresh from the field, that is, undried in the air, was used. These pots were planted in duplicate to onions, millet, and cowpeas.

The influence upon plant growth is well shown in the accompanying illustration. (See Pl. III.) The plants as shown are three months old.

The above illustrations represent plant growth upon the sandy soil. The results upon the red clay soil, while different in certain instances,

[1] Hawaii Sta. Bul. 30 (1913).

as a whole are very much the same. A very poor stand was obtained in all the pots of red clay soil, for which reason no illustrations are submitted.

ONIONS.

The influence of partial sterilization upon onions was very marked. Volatile antiseptics produced a wonderful increase, while heating in the autoclave was productive of a substance evidently toxic toward this plant. (See Pl. III, fig. 1.)

MILLET.

An increase in vigor of the millet plant was correlated with an increase in temperature at which the soil was sterilized. The plants are more vigorous in the pots sterilized by heat than those sterilized by antiseptics. It appears that the organic substance having a toxic influence upon onions is without effect upon millet, for in the pot heated in the autoclave, the plants are as vigorous as any others. (See Pl. III, fig. 2.)

COWPEAS.

In case of cowpeas, the increase in temperature at which the soils were sterilized resulted in a steady decrease in vigor. While the volatile antiseptics lowered the vigor to a slight extent, their influence is not so marked as heat. These results clearly show the intimate relationship between leguminous plants and bacterial life in the soil. (See Pl. III, fig. 3.)

REPORT OF THE AGRONOMY DEPARTMENT.

By C. A. Sahr.

The work of this department consisted largely in the continuation of the lines followed in previous years. The unusually long droughts handicapped the agronomic work on fields not provided with irrigation facilities.

Repeated failures with both sweet and field corn on the station grounds clearly demonstrated the necessity of an adequate irrigation system to insure this crop against irregular seasons when grown outside of the corn belt of the islands. While many insects attack corn, the damage they do is nominal if the plant is grown under favorable conditions. As soon as the crop becomes checked in growth by drought and the whipping action of heavy winds, insect attacks render the crop unprofitable even as silage.

A fertilizer and rotation test with Reid Yellow Dent corn No. 901 was begun, the crop being planted October 1, 1914, and harvested January 9, 1915. The results were so contradictory that no generalizations can be made from them.

SOIL AERATION TESTS WITH RICE AND TARO.

Experiments to ascertain the effects of soil aeration between crops upon the actual yields of submerged crops were conducted with rice and taro.[1]

The plat under test was divided, one-half being given a deep plowing early in June to allow aeration of the soil until the time of planting, while the remaining half or check plat was left untouched until plowed September 2. Both plats were planted to rice September 4, 1914, and the resulting crop harvested December 8, 1914. The aerated plat yielded 83.5 pounds of rice paddy as compared with 71.5 pounds on the nonaerated portion.

A second test, to serve as a check upon the first, was conducted on the same plats. However, the order of the plowing was reversed, the aerated plat of the first test serving as a check plat under the second test. Owing to the late maturity of the previous crops, the aerated plat had but 30 days over the check plat. Both plats were planted to rice on February 18. Here again the yield on the aerated

[1] For results of a study of the effects of aeration on ammonification and nitrification in Hawaiian soils see Hawaii Sta. Bul. 37 (1915).

plat was the greater, 96.25 pounds of rice paddy being harvested from the aerated plat and 78.5 pounds from the nonaerated one.

In the soil aeration tests with taro, the aerated plat was given a deep plowing on June 10, 1913, while the nonaerated plat was plowed on September 10, 1913. Both plats were planted with white taro September 14, 1913, and harvested after a period of 14 months. The results of this test showed a slight increase in the yield of taro and a reduction in the percentage of diseased corms which may be attributed to soil aeration.

These tests are but preliminary work on soil aeration. As the land has been found to be quite unsuitable for definite results, these tests, which were conducted in Nuuanu Valley, have now been transferred to a plat in Waiau, which has been known to be under cultivation of aquatic crops, rice and taro, for 25 years.

Some depression exists among the local rice growers owing to the fact that island-grown rice can hardly compete with the Texas-grown product. At this time many rice growers are hesitating in regard to the further planting of their lands to rice, the inclination being to plant partially to forage crops for maintenance of cattle and hogs. The need of a good system of rotation for this particular type of soil is manifest, and the problem will probably be solved with the cooperation of the more intelligent rice planters.

POTATOES.

Experiments with potatoes included variety, fertilizer, and spraying tests, but the exceedingly dry and hot weather conditions materially affected the results.

In a fertilizer and spraying test with Early Rose potatoes, involving 10 plats of one-twentieth of an acre each, only the 6 lower plats produced plants, the 4 upper plats receiving too small a share of the prevailing light rains to start the eyes properly. This observation was substantiated by actual moisture-content tests taken at a depth of 6 inches in the soils of the upper and lower plats. The soil of the upper plats showed 16 per cent water, while that of the lower plats showed 24 per cent.

The test of spraying with Bordeaux mixture and lime sulphur on Early Rose potatoes resulted in yields of 15 bushels for the check, 25.9 bushels for lime-sulphur spray, and 30.2 bushels per acre for the Bordeaux mixture.

LEGUMES.

Among the new legumes received for trial are three red clovers from Switzerland, Ladino, white clover, and white sweet clover (*Melilotus alba*). These were planted among other legumes on February 18,

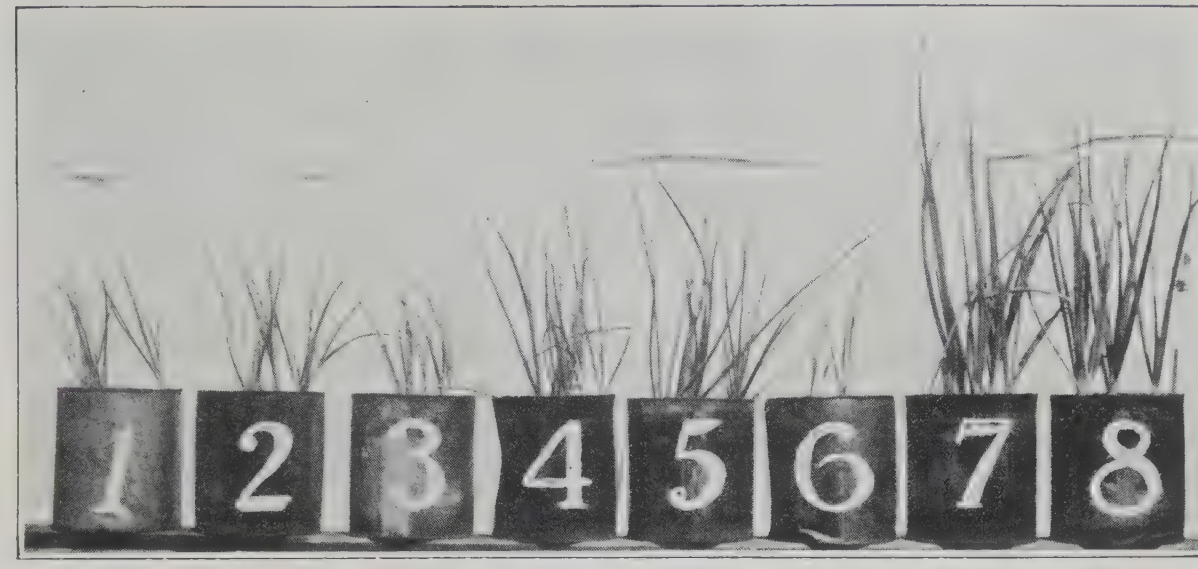

FIG. 1.—ONIONS.

FIG. 2.—MILLET.

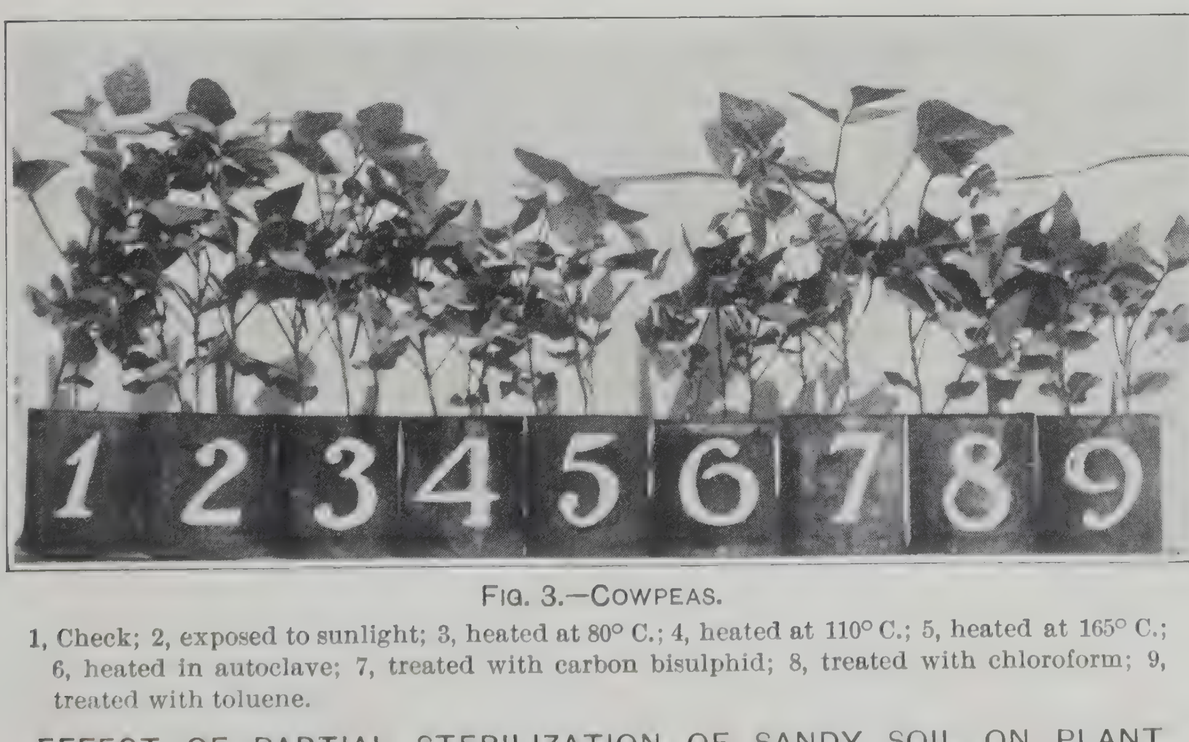

FIG. 3.—COWPEAS.

1, Check; 2, exposed to sunlight; 3, heated at 80° C.; 4, heated at 110° C.; 5, heated at 165° C.; 6, heated in autoclave; 7, treated with carbon bisulphid; 8, treated with chloroform; 9, treated with toluene.

EFFECT OF PARTIAL STERILIZATION OF SANDY SOIL ON PLANT GROWTH.

FIG. 1.—PLAT OF JAPANESE MILLET ON STATION GROUNDS.

FIG. 2.—PARTIAL VIEW OF SEED PRODUCTION TESTS OF LEGUMES VALUABLE FOR GREEN MANURE.

the three red clovers from Switzerland sending out their first blooms during the third week of June, when only a little over a foot in height. All the true clovers (*Trifolium* spp.) are recommended only for high, moist localities. The white sweet clover is very similar to alfalfa, though inclined to bloom considerably later.

Crotalaria mesopontica, introduced here in April, 1914, made a slow growth until fall, attaining a height of 2 feet during the winter months, in which period the plants produced profuse blooms and pods. Another species of Crotalaria (*C. madurensis*) from Ceylon, planted April 15, 1914, had already made considerable growth by July 1. Like the other Crotalarias, this Ceylon variety is likely to earn a place among green-manuring crops for Hawaii. The two wild species of Crotalaria (*C. incana* and *C. striata*) have been planted in green-manuring tests, but fail to respond well to cultivation, the seed not germinating with the first rains, but beginning to appear some weeks later when the soil has become well settled.

In a series of sewings made with jack beans and species of velvet beans, seeds which were sown in early September made the most prolific yields of both green matter and seed. The jack bean, Yokohama bean (*Stizolobium hassjoo*), ashy pod bean (*S. cinereum*), and *S. capitatum*, matured in the middle of January. The Florida velvet bean and Mauritius bean matured one month later.

In a test for yields in forage of alfalfa under natural conditions of rainfall a Spanish alfalfa from Teneriffe and a Utah and Kansas strain of common alfalfa outyielded Peruvian and Turkestan. Given in the order of their merit, the yields in pounds of green forage per annum are: Spanish, 56,362; Kansas common, 52,065; Utah common, 45,245; Peruvian, 35,530; and Turkestan, 30,595.

Semipalatinsk alfalfa or Sholteek (*Medicago falcata*) failed to make a showing equal to that of the ordinary alfalfas or of Japan clover (*Lespedeza striata*).

SMALL GRAINS.

Further experiments with wheat, oats, rye, and barley show but small yields of grain under conditions similar to those on the station grounds. The season required from time of sowing to maturity is 5 to 6 months in duration; therefore the growth is too likely to be interrupted by long periods of drought for successful crops other than those for pasturing or green-manure purposes.

SORGHUMS.

The results of an experiment with a sweet sorghum, a non-saccharin sorghum, and Japanese cane for yields of forage over a period of 453 days were given in the last annual report. The total

yields per acre (green weight) for a period of 26½ months for the sorghum and 27 months for the Japanese cane are: Sweet sorghum, 8 cuttings, 86.55 tons; nonsaccharin sorghum, 6 cuttings, 88.45 tons; and Japanese cane, 3 cuttings, 157.64 tons.

Two other sorghums, African No. 307 (S. P. I. No. 25341) and a durra, No. 760 (S. P. I. No. 27878), have given splendid yields of forage, averaging 15 tons per acre per cutting at periods of 90 to 100 days. Of the sorghums under test for forage yields, Sugar Drip, milo maize, and feterita have shown a tendency to head out too early, or at least before putting out a large amount of leaf surface, the plants appearing weak and spindling. Kafir corn, while stronger growing than either milo maize or feterita, does not seem to show the drought resistance of Sugar Drip, Amber Cane, and the nonsaccharin, long-season African sorghums. Recent observations by the writer have brought to light an inclination among farmers to send to mainland seed firms for sorghum seed without specifying the type of sorghum wanted to supply their particular needs. The seed firms naturally fill such orders with their poorest sellers, usually a kafir or milo maize, which often fail, even with irrigation, to supply profitable yields of forage.

GRASSES.

Of the several forage grasses under trial, Sudan grass still maintains the lead which it gained soon after its introduction into this Territory by its prolific yields of succulent forage. In various tests this grass has yielded from 10 to 40 tons of green forage per cutting, still heavier yields resulting from ideal conditions of soil and rainfall being recorded. Tunis grass has proved valuable as a forage grass at high elevations. In comparison with Sudan at a low elevation, Tunis grass yielded an average of a little less than 4 tons per cutting per acre for six cuttings, while Sudan yielded an average of 14½ tons per cutting per acre for seven cuttings.

Molasses grass (*Melinis minutiflora*) has gained considerable favor in the Hamakua district of Hawaii. The farmers of that district prefer the molasses grass to either Australian water grass or Para grass.

Wilder grass (*Andropogon* spp.), introduced into the Territory by Mr. G. P. Wilder in 1913, has produced excellent results where sown for pasturage. This grass is very slow in its early growth, the first blooms appearing about 120 days after germination. If used as a forage crop, Wilder grass should be cut immediately upon the appearance of the first flowering heads, because the long awns on the flowering glumes interfere with its use as forage. The station plat, planted with roots received from Mr. A. F. Judd in December, 1913,

was cut for seed in June and October, 1914, and in January, 1915, and on being cut for forage May 29, 1915, this plat yielded 11.25 tons of green forage per acre.

Australian blue grass (*Andropogon sericeus*) is another valuable pasture grass for the lowlands. Its habit of growth is very much the same as that of Wilder grass, but it is a little more erect and somewhat less leafy at the bottom. Two cuttings of this grass averaged 9.5 tons green fodder per cutting per acre.

Giant Bermuda grass has met with most requirements of the average ranger for both pasturage and forage. It is adapted to all elevations up to 4,000 feet. Cuttings of this grass set out in soft, moist soil make little headway until the soil has become thoroughly compact. When once started, its growth is persistent.

Teff, Mitchell grass, wallaby grass, side oat grama, Judd, and American buffalo grass (*Bulbilis dactyloides*) have continued to persist under unusual conditions of drought for nearly two years.

BUCKWHEAT.

Further tests with Japanese buckwheat and Silverhull buckwheat were carried out in Nuuanu Valley, where greater moisture and apparently cooler conditions resulted in heavier yields of buckwheat than were obtained in any trial on the station grounds. The Japanese buckwheat matures a week earlier than the Silverhull and yields about 25 per cent more grain.

JAPANESE MILLET.

Trials with Japanese millet, undertaken at various periods, resulted in very good yields of forage when cut green, and of roughage and seed when allowed to mature. (See Pl. IV, fig. 1.) If grown for soiling purposes, millet must be cut when the flowering heads first appear, which is usually about 60 days from planting. Millet matures in 80 to 100 days under ordinary conditions, and its best period for cutting for forage value is limited to 8 or 10 days. Yields of 12 tons of forage per acre when cut green, and 3 tons roughage and 30 bushels of seed per acre when left to mature, are the approximate yields of the station plantings. As a soiling crop, millet is planted to best advantage in November and December, and harvested in January and February, the cool-weather months when sorghum yields are low.

NUT GRASS CONTROL.

The best results in controlling the spread of Japanese nut grass have been accomplished so far by spraying with arsenite of soda. Advantage is gained by spraying when the nut grass is heading out,

thus killing the growth above the surface of the soil and causing the stem below the surface to rot. Spraying in single applications, however, will not kill the underground bulbs, and new shoots will again appear after a week or 10 days. Following each application of arsenite of soda, all dead growth is burned off as soon as it is sufficiently dry, thus leaving the ground bare of growth. The new shoots of nut grass are then more easily accessible to the spray. Persistent spraying at the proper time to prevent seeding may eventually sap the vitality of the underground bulbs, finally killing them.

Other methods of eradication under trial are cutting frequently at the surface and plowing with a disk plow. The results of these methods at this time are not conclusive.

COTTON.

That paying crops of Caravonica "wool" cotton can be grown in the Kona district in spite of the pink bollworm (*Gelechia gossypiella*) is indicated in the continual demand for cotton seed from the homesteaders of that district to extend their cotton fields.

Of the stand of Caravonica "wool" cotton planted on the station grounds in February, 1910, two rows have been retained to furnish data on longevity and yields. The average yield per tree per annum, when grown for four years, has been approximately 1 pound of lint. The rows are 10 feet apart, with the trees 10 feet apart in the row.

Small stands of Sea Island, Egyptian Yuma, and Upland cotton are maintained annually to supply selected seed for distribution.

SEED DISTRIBUTION.

There has been a demand chiefly for soiling and pasture and pasture crop seed, Sudan, Wilder, Australian blue, teff, Tunis, and Mitchell grass seed, while roots or cuttings of Giant Bermuda and some other grasses have been eagerly sought. In the distribution of all seed particular pains have been taken to supply the homesteader with seed of crops particularly suited to his needs and environment. No attempt has been made to supply seed of field or sweet corn other than for trial plantings. A number of the more promising legumes are being grown for seed for limited distribution to farmers for cooperation tests. (See Pl. IV, fig. 2.)

REPORT OF THE EXTENSION DIVISION.

By F. G. Krauss.

INAUGURATION OF THE WORK.

The present agricultural extension work of the station was definitely inaugurated in November, 1914, when the present superintendent was appointed to take charge of the work. This work was provided for by a special fund of $5,000 added to the regular appropriation for the Hawaii Agricultural Experiment Station. Previous to this, the extension work of the station was confined largely to projects provided for by local appropriations by the Territorial legislature. Most of the substations which were of nonexperimental character were provided for in this way. It is hoped eventually to correlate all extension and demonstration work under one head.

Hawaii is peculiar in that it has no established diversified agriculture with its usually associated groups of small independent land holdings so familiar on the mainland. Many efforts have been made to homestead various tracts of the public lands of the Territory, but no examples of markedly successful small farm communities are existent. The reason has been twofold: The establishment of communities of farmers in sufficient numbers to insure their stability can not be hoped for until it has been demonstrated by actual test that a variety of crops other than the few main staples now grown can be produced economically on a commercial scale, and that, various crops having been so grown, a profitable market can be developed for their disposal.

The lack of organized effort is doubtless the chief reason why greater success has not been obtained in the past. The Hawaii Experiment Station, and through it a few scattered farmers, have demonstrated that a large variety of crops now imported from the mainland, as well as many of those peculiar to the Tropics, can be successfully grown throughout the islands. The newly created marketing division has proved that most of such products find a ready sale, either locally or on the mainland, if delivered regularly in good marketable condition and sufficient quantity. It is the object of the new agricultural extension division to correlate these facts and to make known these and various other facilities of the United States Department of Agriculture for the direct benefit of the farmers of

Hawaii. The success that will accrue from this movement will be measured in large part by the extent to which the farmer will cooperate with the extension division.

The establishment of the Glenwood and the Hilo substations on Hawaii, the Nahiku substation on Maui, the Waipio substation on Oahu, and the Homestead substation on Kauai, together with the marketing division in Honolulu, constituted the initial cooperative effort made to aid the farmer in realizing a more normal and profitable agriculture. The establishment of a demonstration farm in the midst of the Kuiaha-Pauwela homestead tract, near Haiku, on the Island of Maui, is the direct outgrowth of an organized effort of the homesteaders to obtain this Government cooperation for which the extension division was created. It may be said to have been born of economic necessity. A group of some forty American families have cast their lot in an agricultural venture which promised well because of its favorable location and the apparent assurance of a safe and profitable crop. The successful culture of pineapples had already been demonstrated. A flourishing canning establishment was running to full capacity, and what appeared to be satisfactory contracts were entered into by the homesteaders for the disposal of their fruit. The unprecedented rains of 1914 proved disastrous to a large part of the crop, and the slump in prices (due to the troubled conditions in Europe, together with the general overproduction from new acreages) brought home in a striking manner the uncertainties of a single-crop system. The older pineapple growers had already found that successive plantings of pineapples on the same ground invariably give declining yields, regardless of fertilization and any reasonable period of fallow thus far practiced. The demonstration farm at Haiku, Maui, has under way as one of its most important projects the working out of a cropping system, which shall consist of a rotation of crops that will be beneficial to the land and of immediate cash value as well. Fortunately three or four out of the many leguminous crops already tested out on a field scale are promising for use in rotation with pineapples, which crop, it is generally believed, will remain a staple in the locality in question.

MISCELLANEOUS DEMONSTRATIONS.

Next in importance to the work of general organization of the newly created extension division is the practical farm demonstration and cooperative marketing work recently inaugurated on the island of Maui, which is to be extended as rapidly as possible to all the islands of the group.

The principal farm demonstration work on Maui is being centered on two homestead units in the Kuiaha-Pauwela tract near Haiku. The main work in cooperative marketing which has been carried on in the Kula district is also being centralized at Haiku. The work has recently been broadened to include the whole of Maui, and the other islands of the group will be given attention as rapidly as the limited means at hand will permit.

In addition to the experimental and demonstration work being carried on at the demonstration farms in the Kuiaha-Pauwela homestead tract, four extensive cooperative experiments and demonstrations and a number of minor trials are now under way on the island of Maui. A number of additional projects have been planned for the coming fall months, chiefly in the Haiku and Kula districts of Maui.

At Kula a farmers' cooperative marketing association, with a membership of over 100, has been organized and considerable farm produce marketed through it.

On both the farming and marketing phases of the extension work, as well as on the educational side, many difficult and complex problems are offered for solution. It will be especially difficult here, as elsewhere, to organize the farmers for cooperative action. The average farmer of the islands is not a business man and has not yet learned the economy and efficiency to be derived from cooperating with his neighbors. The more popular publications of the United States Department of Agriculture have been given a wide circulation among the farmers of the Territory.

One of the most important undertakings that has been imposed upon the extension division is the working out, into practical demonstrations, of efficient cropping systems whereby the fertility of the lands now being devoted to pineapple growing may at least be maintained if not improved. A permanent agriculture can not be built up under the present systems of crop and soil management as practiced even by the most advanced pineapple growers. The customary successive plantings of pineapples on the same land have invariably produced diminishing yields, even when the land has been left to lie fallow for a number of years between plantings. While a few desultory attempts have been made at green manuring pineapple lands, no systematic experiments in practical crop rotations and green manuring have been recorded. There appears to be no valid reason why the well-established principles of soil management, as they apply to other crops, should not be applicable to pineapple culture. It will be the aim of the extension division to make practical applications of many of the improved methods worked out by the

Hawaii Experiment Station, which, because of lack of practical demonstration, have not been brought home to the farmers with sufficient force to induce their adoption.

Real extension work in agriculture can not long ignore agricultural education. Such education and training has only as yet been hinted at in Hawaii, while on the mainland this important phase of extension work is receiving most careful study. The majority of rural inhabitants can not attend agricultural high schools and colleges. For these the best possible educational advantages should be brought to the farms and homes.

DEMONSTRATION FARMS.

The main farm demonstration work on Maui is being centralized on two homestead units situated in the Kuiaha-Pauwela tract near Haiku. The two farms are representative of average conditions in the lower and middle section of the homestead tract and apparently of a large part of Maui.

The lower homestead is in the drier section of the Makawao region. The average rainfall is about 40 inches per annum. Climatically this section appears to be well adapted to diversified and intensive agriculture. This particular homestead was among the first to be settled upon, the original settler planting his first crop of pineapples in 1911. An excellent crop of fruit was harvested in 1913, but in the succeeding year many of the plants sickened, and the yield of fruit was greatly reduced in consequence. Owing to financial difficulties, the original settler abandoned the farm in the fall of 1914. It was taken over by the superintendent of extension for demonstration purposes in January, 1915. The crop for 1915, both from old and new plantings, was practically negligible. In the sheltered portions of the farm fine vegetables in considerable quantity were grown. Both bananas and papayas, though now growing without care, are of excellent quality. The pineapple fields, consisting of about 10 acres, were abandoned to weeds, as it was considered hopeless to restore them to profitable production. However, about 50 tons of pineapples weighing a little under 3 pounds each was produced.

Immediately upon taking possession of the lower homestead, a tract of 16 acres was cleared of brush, the main growth being heavy grass sod and young guava which had sprung up after 1½ years of abandonment. The land was then given 3 plowings, 6 disk harrowings, and 2 draggings at a cost of $40 per acre for the tillage operations. This cost is on a basis of $6 per day for a man, 3 good working mules, and implements. The first crops were planted on May 6 and the last on May 28, 1915. The following crops have been planted for demonstration purposes.

FIG. 1.—BEANS AND CORN INTERCROPPED, PINEAPPLES IN BACKGROUND, HAIKU DEMONSTRATION FARM.

FIG. 2.—PREPARING GROUND IN PINEAPPLE FIELD FOR DYNAMITING, HAIKU DEMONSTRATION FARM.

FIG. 1.—DETAILED VIEW OF HONOHONO, A VALUABLE SOILING CROP FOR DAIRY CATTLE, GLENWOOD SUBSTATION.

FIG. 2.—SILO AND GENERAL VIEW OF THE GROUNDS OF THE GLENWOOD SUBSTATION.

Crops grown on the lower demonstration farm.

Crops.	Number of varieties.	Method of culture.
Field corn and beans	4 each.	Intercropped.
Jack beans for seed	1	In rows $2\frac{1}{2}$ and 5 feet apart.
Sunn hemp	1	In rows $2\frac{1}{2}$ feet apart, 25 and 50 pounds seed per acre.
Soy beans	4	Inoculated and not inoculated.
Pineapples	1	Ordinary.
Do	1	To be plowed under and green manured.
Para grass	1	Broadcast.

The middle demonstration farm is a well-established homestead. The equipment in farm buildings, farm machinery, implements, work animals, etc., is among the best in the Kuiaha-Pauwela and Kuiaha-Kaupakuhua homestead tracts which surround it. Systematic plantings have been made each year since the homestead was settled in May, 1912. While the main crop has been pineapples, for which the lands are especially well adapted, a cropping scheme is in operation which includes a definite rotation system. The crops employed are shown in the following table:

Crops grown on the middle demonstration farm.

Crops.	Number of varieties.	Crops.	Number of varieties.
Pineapples, 1, 2, and 3 years old	1	Peanuts	4
Corn	2	Watermelon	4
Legumes	4	Artichokes	1
Potatoes	8	Field beans	2
Sweet potatoes	3	Forage grass	2

The young pineapple plantings are being subjected to intercroppings of dwarf field beans, as are also some of the plantings of corn. (See Pl. V, fig. 1.) The success of this demonstration has introduced the practice among a number of local pineapple growers. A series of fertilizer, tillage, and dynamiting experiments with pineapples is also under way. (See Pl. V, fig. 2.) All crops grown are under fertilizer, liming, and tillage experiments. Careful records are being kept of all farm operations, and it is expected that these data will prove valuable to prospective homesteaders.

COOPERATIVE EXPERIMENTS.

In April, 1915, a 6-acre, cooperative, green-manuring, and legume-rotation experiment with pineapples was entered into with the Haiku Fruit & Packing Co. A project was worked out whereby the influence

of green manuring and rotation over a period of five years can be determined. Four leguminous crops are under test. The company furnishes the land, labor, and seed, while the extension division gives general supervision when such becomes necessary. The work is being unusually well done by the company and valuable results are expected.

A private planter has requested the services of the extension division in carrying on cooperative experiments in dynamiting and in treating soils antiseptically in pineapple culture, the land, labor, and materials all being supplied by the owner, who is one of the most advanced planters in the district. Another pineapple planter, who is entering into the dairy business, is undertaking a cooperative forage-crop and pasture-grass experiment. Largely through the suggestion of the extension division, this same farmer has acquired a herd of pure-bred Jersey cattle.

Early in the spring, through the advice of the extension division, an acre of beans was planted by each of some 20 homesteaders and others. The crops from all these tracts have been harvested and nearly all have been thrashed and marketed. It is hoped that bean culture may in time become as important an industry in this region as it already is in Kula.

Fifty pounds of Sudan grass has been distributed in the district, mostly in 1 and 2 pound lots, for trial and report. One grower reports that but for his half-acre patch of Sudan grass he would have suffered materially for forage for his dairy herd.

Four different projects have been planned and three are under way for cooperative leguminous crop demonstrations. These will be located along the main road running through the Kuiaha-Pauwela homestead tract. The value of these legumes has already been demonstrated on the extension division farms. The most promising kinds are jack beans, velvet beans, sunn hemp, and cowpeas. These are valuable for green manuring and forage, as well as for their seed which is now beginning to be eagerly sought by the sugar plantations.

The cooperation of the Territorial office of public lands and the division of forestry has been secured, and it is hoped that newly opened homestead tracts throughout the islands may hereafter have at the outset whatever assistance the extension division may have to offer.

In the newly surveyed Makawao homestead, which is shortly to be opened for settlement, a homestead unit is to be set aside for agricultural demonstration under the supervision of the extension division. It is also planned to reserve wide tree belts as a protection against the excessive winds that prevail there. Mr. C. S. Judd, chief forester of the Territory, is to give this matter his personal attention.

REPORT OF THE GLENWOOD SUBSTATION.

By F. A. Clowes.

During the year the work of the substation has been continued along lines similar to those indicated in previous reports. The most interesting features of the crop work are the use and value of honohono for a soiling crop, *Paspalum dilatatum* for pasture, and cane tops for silage. Excellent results have been secured with chicks kept according to approved methods, and a flock of 250 pullets has been raised and housed in colony houses designed from standard plans, but altered slightly to suit local conditions. Considerable extension work has been carried on with excellent results.

HONOHONO (*Commelina nudiflora*).

From May 1, 1914, till April 30, 1915, the yield of honohono from a plat 10 feet square, which was a representative part of the field, was weighed at each cutting. The total yield of green feed per acre, calculated from this plat, was 223.6 tons (Pl. VI, fig. 1).

Honohono is an extremely succulent feed, much relished by cattle. Cattle fatten and produce an abundance of milk when pastured where it is plentiful. A study of the records of one of the pioneer dairymen at Glenwood shows that during a 29-month period, at a time when honohono was abundant, his herd of 33 cows of mixed breed gave an average annual milk flow of 6,100 pounds of milk per cow. The highest 12-month record was 8,616 pounds, and the lowest was 3,092 pounds. One dairyman in the same region secured a yield of 11,000 pounds from a Holstein cow fed honohono. It is believed that the yield of green feed recorded at the substation is not exceptional. Calculated from analyses reported by the station,[1] a ton of green alfalfa would contain the same amount of protein as 4.7 tons of honohono. Looked at in another way, 223.6 tons of honohono, the yield of 1 acre, would contain the same amount of protein as 47.6 tons of green alfalfa, which would be considered an exceptional yield from an acre in one year. For the food constituents other than protein, the comparison is even more favorable to honohono. To cultivate honohono, an abundant supply of manure

[1] Hawaii Sta. Bul. 13 (1906).

is necessary. This would be readily available were adequate provision made for the stabling of the cattle, as suggested elsewhere in this report. The cultivation of honohono as a soiling crop is proving very satisfactory in this region.

PASPALUM DILATATUM AS A PASTURE GRASS.

As a pasture grass, *Paspalum dilatatum* has given excellent results. Its strong deep root system enables it to withstand the tramping of stock in wet weather better than any other grass tested at Glenwood that is equally relished by the cattle. It has been extensively planted by local dairymen since its introduction by the substation. Both seed and divided roots have been used for planting. Homesteaders have been supplied liberally with roots from the fields of the substation.

CANE-TOP SILAGE.

The silo (see Pl. VI, fig. 2) was filled during June and July, 1914, with cane tops from neighboring fields. The weather during these months was excessively wet. The roof was not put on the silo till filling was almost completed, and as a consequence, much water found its way into the silo. The cane tops were bundled in the field and loaded on cane cars on the portable track used by the Olaa Sugar Co. in getting out the cane. The cars when loaded were hauled to a convenient place, and the tops were transferred to a wagon and hauled to the silo. Owing to various unavoidable interruptions, the silo filling was greatly delayed, and the silage was expensive. Some of the cane tops were cut two weeks before they were put into the silo. Notwithstanding the resulting staleness and the excessive amounts of water that went into the silo during filling, the silage was of fair quality and was eaten readily by the cattle and horses. To adapt the silo to profitable use for cane tops, it should be so located that there will be a minimum amount of labor in getting the cane tops into the silo. Since the economical use of the manure is a factor of controlling importance in any scheme for the use of considerable quantities of cane tops, the location of the silo and the feeding yard should be such that the manure can be supplied to the fields without too long a haul. The yield of cane tops per acre is about 10 per cent of the weight of the usable cane. On the unirrigated plantations this by-produce would run from 4 to 8 tons of cane tops per acre. These amounts are equivalent to about half the yield of corn silage secured by the live-stock farmers. A comparison of analyses of corn silage and cane-top silage indicates that the cane-top silage and corn silage are probably not greatly dissimilar in feeding value. This being so, it only remains to develop satisfactory practical

methods to produce, on every acre of cane land, a crop of beef, milk, or butter as a by-product of the sugar industry. This would ordinarily be equal to one-half of the main crop of the live-stock farmer elsewhere. In the feeding of silage to secure economical returns, supplementary grain feeding appears to be necessary. With judicious care of the manure, the fertilizing elements secured through the use of these grain feeds would replace much of the commercial fertilizer at present imported.

CATTLE.

During the year the station loaned the herd bull, Raymond of Alta Vista, to the Board of Commissioners of Agriculture and Forestry for four months, and he was placed by them at the Hilo Quarantine Station, where 15 cows were brought to him for service. This arrangement distributed his service over a large area without inconveniencing the Glenwood homesteaders to any extent.

The herd now consists of 1 registered Guernsey bull and 3 registered Guernsey cows, 1 registered yearling heifer, 2 registered heifer calves, and 2 unregistered Jersey cows. To adequately demonstrate the best methods of caring for cattle, the herd should be increased to 10 or 15 milking cows. Funds are not at present available for this purpose.

In the earlier part of the year, just previous to calving, one of the Guernsey cows, Kitchener's Vimera, was much troubled with sore feet, which, with the exposure to the heavy rains and the strain incident to parturition, kept her in very poor condition for several months. During wet seasons like the summer of 1914, the feet of cattle at pasture develop raw sores in the flesh between the divisions of the hoof. The horn on the inner surface of the hoof also becomes pitted and decayed, and the toes become sore. The horn of the hoof sometimes becomes much elongated, commonly reaching a foot in length unless trimmed. This lengthening is due to the absence of hard ground, which would ordinarily wear off the natural growth of hoof. The weight is then thrown back upon the rear of the hoof, thus adding to the other discomforts. Unless given attention, cows become so lame that they are unable to graze over a sufficient area while at pasture to keep them in good condition. By trimming off the surplus horn, by washing between the claws and applying antiseptics, and by keeping the animals out of the mud, cures are easily effected. Three of the cattle at the substation developed these troubles in the earlier part of the year before an extension of the stable made it possible to shelter all the stock.

When any considerable number of animals is affected their care becomes a serious burden unless adequate stabling is available to per-

mit of the animals resting on dry ground during heavy rains and at feeding times. The heavy rains, even when they do not cause sore feet, affect adversely the condition of the cattle, no matter how much they are fed, unless they can have adequate protection. On account of these facts outlay for stables and covered yards can be made a profitable investment. The value of the manure saved by providing concrete floors in these shelters would eventually repay the cost of the concrete construction. In July the station stable was extended to provide cover for all the stock.

FARMING OPERATIONS.

Throughout the whole region on the windward side of Hawaii and Maui the weather was so wet from the first of April to the end of September, 1914, that field work, with the exception of the unavoidable cane harvesting, was at a standstill. At the end of September, when the weather was comparatively clear and cultivation was possible, the fields were quickly restored to good condition, and little injury resulted to growing crops. In the cane fields effective results were obtained in weed control by the use of arsenite of soda on the dense growth. This destroyed at one spraying stands of weeds that would have taken several cultivations to subdue. At the substation no advantage could be taken of the good planting weather in the fall, since funds for the pay of labor were not available on account of the curtailment of the Territorial allotments. On this account no plantings were made from April, 1914, until April, 1915. Seasons such as that of 1914 occur only occasionally and do not prevent farming operations where the operators are not hampered by adverse circumstances other than the weather. Their occurrence does, however, point to the necessity of placing chief reliance on perennial crops such as the pasture grasses, Para grass, honohono, sugar cane, sorghum, and others that will undoubtedly come into favor with the greater use of cultivated crops in connection with the live-stock industry.

POULTRY.

The greatest drawback to poultry culture in Hawaii is the prevalence of a number of contagious diseases. Probably the most troublesome of these is sorehead.[1] It is very destructive to young chicks, but not to mature fowls. The method by which this disease is carried from fowl to fowl is not definitely known. Mosquitoes and insect parasites probably play an important part. The disease is most prevalent during the warm months from May to September. It has been the experience of many that early hatched chicks either escape

[1] Hawaii Sta. Press Bul. 46 (1914).

the disease altogether or recover from the attack. Incubator-hatched chicks, brooded artificially and kept from contact with other fowls, are less frequently affected than chickens brooded under hens. Chicks kept off the wet ground and properly cared for under cover till 6 or 8 weeks old are less frequently affected than those allowed on the ground at an earlier age. Well-fed chicks, given abundant exercise, are likewise less frequently troubled than neglected chicks.

There has been no contagious sickness among the birds at the substation. This is attributed to the fact that care has been taken to prevent contact with other birds. The houses are disinfected regularly, and the chicks are hatched early in the season. At the close of the breeding season in 1914 and before any of the chicks were put out of the chick pens, the breeding flock was disposed of, and the chicken houses were thoroughly cleaned and disinfected before placing the chicks in them. With the exception of three male birds, purchased for breeding purposes, the entire flock has been hatched in incubators and raised on the place, free from contact with other fowls. The roosts and dropping boards have been sprayed bimonthly with a mixture of 4 parts crude oil, 2 parts kerosene, and 1 part creolin. The houses are thoroughly cleaned annually and sprayed inside and out with the above mixture. As a result the birds have not been troubled with lice and mites, which in large measure explains the absence of disease. At the commencement of the fiscal year there were in the station flock 38 White Leghorn pullets and 12 Rhode Island Red pullets. One Rhode Island Red pullet was killed for examination. She was apparently healthy and fat but laid no eggs, although she entered the trap nest regularly. A post-morten examination showed that the abdominal cavity was filled with soft-shelled eggs, flattened out, and occupying all the space not filled with the intestines and other abdominal organs.

Throughout the year the flock was fed on commercial scratch feed scattered in the litter during the day and in a hopper just before night. The total consumption by the flock for the 12 months was 1,800 pounds, which cost $45, or 36 pounds per bird at a cost of 90 cents per bird. As the birds had free range, they picked up a large part of their living. During the year 4,204 eggs were produced. Part of the feed cost should be correctly chargeable to increase in the weight of the birds, but charging it all to the eggs, the cost per egg for the grain feed was 1.07 cents. The average wholesale price of eggs in Honolulu was about 43.5 cents per dozen, from which must be deducted the freight and marketing charges of about 5 cents per dozen.

Colony houses of four designs have been erected to determine their relative suitability. The design that seems most satisfactory is of the

shed-roofed type, 10 feet square, built of surfaced, tongued, and grooved northwest fir, with ceiling over the roosts for ventilation, built-in dry mash hopper, roosts for 50 birds, and 15 trap nests. The cost of each house was $60. Allowing for 5 per cent depreciation and 5 per cent interest on the investment, the cost of housing per bird would be 12 cents per year.

EXTENSION WORK.

Through the month of July the superintendent of the substation was instructor in agriculture at the summer school for teachers under the auspices of the department of public instruction.

Through the suggestion of the substation, the cooperation of a number of civic organizations was secured for the holding of the first Hawaii County Fair at Hilo. The superintendent of the substation was the chairman of the managing committee of this fair. Great success met the effort expended in this attempt, and the fair is assured as an annual event. It has done much already to stimulate interest in poultry culture and the breeding of better live stock. Its influence on other branches of agricultural production is also considerable.

The boys of the Glenwood School have been given weekly instruction in milk testing at the schoolhouse and later at the substation. The work is now developing along the lines of cow-testing associations. The boys range in age from 8 to 15 years. The parents of each boy are directly engaged in butter making. The boys are much interested in the work and the accuracy of their testing is surprising.

The substation cooperated with the Hilo High School in the operation of a hatchery, and aided in the agricultural work by giving suggestions and advice. The substation supplied the hatchery with 100 dozen eggs for hatching, and loaned one incubator at the close of the season's hatching at the substation. Through the Hilo High School hatchery over 3,000 pure-bred, day-old chicks have been distributed. Where it was acceptable to the purchaser, advice was given as to the care of the chicks. This advice was naturally more frequently sought by school pupils than by adults. The system of care and feeding advocated was that outlined above as in use at the substation.

In every case where this system has been followed excellent results have been secured. Two cases of sorehead epidemic occurred among the chicks that had been distributed from the High School hatchery, but in both of these cases the chicks had been kept on the ground, contrary to the advice given. Sorehead was very prevalent in the town of Hilo during the months of April, May, and June, 1915. It is noteworthy that no cases occurred among the chicks sold from the hatchery and raised under cover and otherwise cared for according to

directions, including the feeding of dry mash and green feed from hoppers and scratch feed in deep litter. Poultry culture has been greatly stimulated by these efforts.

In recent years the methods of field cultivation on many of the sugar plantations have been greatly changed. At one time most of the field work was done by large gangs of coolies under the supervision of overseers. Gradually this method is being superseded in the interest of efficiency by cutting up the fields into smaller areas, which are leased to small planters.

Most of the plantations near Hilo plan to retain for cultivation by hired labor only sufficient land to profitably employ their labor force during the time the mill is not grinding. A great deal of the homesteading of the public lands has been done by citizens whose training has not been along the line of farming. Where the homesteads have not been sold shortly after being deeded to the homesteader, they are usually rented to the class of tenants that are leasing the lands of the large plantations. There has, therefore, developed a large class of tenant cane growers and a rural social problem, similar to that presented by farm tenancy elsewhere, but complicated by the one-crop system and the fact that the largest landlords, the plantation corporations, also control the cane market of the tenant.

These people, the homesteading landlords and homestead cane growers, have repeatedly appealed to the station for advice and assistance. This work did not fall directly within the scope of the station work, but such assistance has been rendered as seemed to be in accord with the general policy of the department.

HORTICULTURAL OBSERVATIONS IN PORTO RICO, CUBA, AND FLORIDA IN RELATION TO THE HORTICULTURE OF HAWAII.

By J. Edgar Higgins.

In June, 1914, when the writer was about to close a year's leave of absence, instructions were received to report for duty in Porto Rico and proceed to Honolulu via Cuba and Florida, making observations of tropical horticulture en route. Considerable attention had already been given to the fruit industries of Porto Rico, and, after a week or more of further investigation, the steamer was taken, on June 29, direct to Havana. No attempt at an exhaustive study could be made, but much valuable comparative information was obtained, a part of which is recorded herewith, and much of which is on record for reference when required.

THE PINEAPPLE INDUSTRY IN PORTO RICO.

The pineaple industry of Porto Rico occupied during the year 1912 an area of 3,654 acres.[1] The output was valued at $943,445, of which $258,671 represents the value of the canned product and $684,774 the value of the fresh fruit. Thus, less than 28 per cent of the total value of the crop was received for the canned product. The canning of pineapples, however, has been on the increase steadily, but has not increased so rapidly as has the export of fresh fruit, which in 1914 was valued at $1,245,215. The proximity to great markets and comparatively frequent opportunities for shipping account for the more rapid development of the fresh-fruit industry. Steamers ply frequently between the island and New York.

The organization of the industry is quite different from that in Hawaii. There are practically no large corporations in Porto Rico. For the most part the holdings are small as compared with those of Hawaii. There are probably few, if any, individual or corporate holdings in excess of 250 acres. Pineapples are grown almost exclusively by Americans on farms or plantations. There are thus a good many growers interested in the business, but they are very widely separated, being scattered throughout the greater portion of the northern side and the western end of the island.

[1] War Dept. [U. S.], Ann. Rpt. Governor P. R., 12 (1912), p. 135.

CULTURAL METHODS.

As has already been indicated, the pineapple plantations are located chiefly along the northern side and western end of the island. These are all at comparatively low elevations, many being only slightly above sea level and none above a few hundred feet. They are nearly all served by the railroad which extends around the western end of the island from Ponce on the south to many miles east of San Juan on the north.

The soils on which pineapples are grown in Porto Rico are of several types, the sandy and sandy loam predominating along the northern side of the island, with some gravelly loam. Some clay loam, particularly on the western end, is devoted to the industry, and it resembles in appearance much of the pineapple soil of Hawaii. Some indications of manganese are found, but manganese does not appear to have given rise to much difficulty. Drainage is as vital a problem in Porto Rico as in Hawaii. Even the sandy soils are in many cases underlaid by a more or less impervious stratum which makes drainage difficult, particularly on lands with very slight grade.

Propagation methods do not differ materially from those in Hawaii, except that crowns are seldom if ever used. Slips and suckers are used almost entirely. With these is to be included the underground sucker which in Porto Rico is called a ratoon. Perhaps the reasons for the disuse of crowns are that the Red Spanish variety, which is the one most commonly grown, produces suckers abundantly; that these suckers produce fruit much more quickly than the crowns, and, further, that the Cabezona, which is the only other variety of importance, is extremely slow in producing a crop from crowns.

In preparation of the soil a long period of tillage is found necessary, as in Hawaii. The ridge system of planting is much in use, probably because it aids in quickly removing excessive water from the plants in a country where torrential rains are common. Flat planting, however, is seen in many places. About 12,000 to 14,000 plants per acre are set in case of Red Spanish, and various forms of arrangement are employed, some plantings being made as close as 12 by 12 inches in the beds or double rows. Much of the planting is done in the winter, the season of heavy cropping coming in the spring. Some progressive planters have found it possible and advisable to plant in July and thus distribute the season of cropping over a larger portion of the year, getting perhaps 75 per cent of the crop out of season or when there are few pineapples on the market and prices are good.

Pineapples are much used as an intercrop with citrus trees, and this combination, if carefully and wisely handled, sometimes results

in the pineapples practically paying for the establishment of the citrus orchard (Pl. VII, fig. 1). About two ratoon crops are generally taken whether the pineapples are grown exclusively or as an intercrop. Replanting does not usually follow immediately after the destruction of the first planting. It has been found necessary in Porto Rico, as in Hawaii, to prepare the land very thoroughly before the second planting. Where it is possible, fallowing for a year or more is frequently practiced, the land being used for pasture. In the destruction of the old plants, the ever-present machete is very much in evidence. This swordlike tool, which is used by the natives for almost every conceivable purpose in gardening, is very effective in cutting down the old plants. If the growth is dry enough after weeds have been allowed to grow it is sometimes burned over.

The cost of production of pineapples in Porto Rico is apparently about the same as in Hawaii. Pineapple lands, unplanted, cost from \$75 to \$250, the price being determined to a large extent by location. Labor can be secured at 62 cents per day, but because of the larger proportion of handwork and possibly lower efficiency, the planter's labor bill is probably not less in Port Rico than in Hawaii. The yield of pineapples ranges from 10 to 14 tons per acre. Fertilizers are used rather freely and with profit to the grower.

The varieties of most importance have already been mentioned. It is estimated that probably 90 per cent of the crop is Red Spanish. This variety is known to most growers in the Territory of Hawaii, although it has never proved popular here except in the Kona district of the Island of Hawaii. It is a vigorous grower and yields freely. The fruits are of small size, ranging from $1\frac{1}{2}$ to $4\frac{1}{2}$ pounds. They are of good quality, ship excellently, and sell well on the market. They are better adapted to fresh-fruit trade than to canning, because of their small size, which makes it impossible to get a large percentage of slices of sufficient diameter to pack the highest grade of canned fruit. They are, however, much used in canning. The Cabezona is an extremely large fruit, averaging from 8 to 10 pounds, 15 pounds being not uncommon, while fruits weighing 18 to 25 pounds have been reported. This variety has been grown in one locality in Porto Rico since the early part of the nineteenth century and has come to be known in some other parts of the world as the variety Porto Rico. Its origin in the island is not known. It seems well adapted to local conditions, particularly on the loamy soils, and is planted in those parts of the island where canning is being chiefly practiced, since it is not well adapted to the fresh-fruit trade. The Smooth Cayenne variety, upon which the Hawaiian industry is based, is almost never grown in Porto Rico. Many other varieties have been introduced, including the hybrids originated by the United

States Department of Agriculture, but up to the present time none have proved popular for commercial cultivation except the two named above.

DISEASES AND INSECTS.

The diseases of the pineapple in Porto Rico are not materially different from those of Hawaii. Soft rot, due to the fungus *Thielaviopsis paradoxa*, is more or less destructive to fruits in transit, but the Red Spanish variety shows considerable resistance, and by proper care in curing, packing, and transportation this trouble can be rendered unimportant. Base rot, due to the same fungus, is somewhat in evidence, but in the warm soils, if drainage is provided, it does not cause much loss. Leaf spot, also due to this fungus, is found chiefly in the coolest part of the year and in wet weather. Sun scald, following the bending over of the fruit, occurs as in Hawaii, but because of the small size of the fruits and the close planting, the loss is small in the Red Spanish variety. The practice has been followed to some extent of covering these exposed fruits with a little dried grass, the work being performed by children. Pineapple wilt occurs, but usually only where the conditions are unfavorable.

Perhaps the chief insect enemy of the pineapple in Porto Rico is the mealy bug (*Pseudococcus bromeliæ*) which is so common in Hawaii. It is accompanied by ants, which aid in its distribution. When the necessity arises, this insect is held in check by means of sprays. The pineapple scale (*Diaspis bromeliæ*) was not seen by the writer in Porto Rico and was said not to occur in the island.

MARKETING.

The fresh-fruit trade in pineapples from Porto Rico is exclusively with New York as a distributing center, except for a few small shipments which may go to New Orleans. The fruits are shipped in the Florida or Red Spanish crate. The dimensions of this are 10½ by 12½ inches inside measurement and 36 inches long outside. This crate is well suited to the Red Spanish variety. It contains from 70 to 75 pounds of fruit, net weight, averaging about 72 pounds. There are from 14 to 60 fruits in a crate. There are few that run so large as 14's, and very few so small as 60's are shipped. The sizes and approximate corresponding weights are indicated in the table on page 63. The prices received for the fruit of late years have averaged about $2.50 per crate for the sizes ordinarily shipped—that is, from 42's up.

Until 1910 the prices received were very much lower. Up to that time there was no thorough organization of the fresh-fruit trade.

Fruits were shipped by individuals on consignment, and the results were about as unsatisfactory as those generally brought about by this system. At that time the Porto Rico Fruit Exchange was organized, at first having a severe struggle for existence, but now being well established. This is an organization of growers. At first stock was sold to nongrowers, but at the present time a man must be a bona fide grower to secure stock. Each share bears one vote in the control of the organization, and no grower can now buy more than five shares. This organization now ships about 60 per cent of the fruit grown in Porto Rico for export. It is estimated that about 85 per cent of the growers are members of the organization, but because of the heavy shipments of a few comparatively large growers, who ship independently, less than 85 per cent of the fruit is controlled by the organization. The shipping of these larger growers, however, is organized on a business basis, so that it does not demoralize the market as is always done by a large number of small growers shipping to a distant market without organization. The exchange handles about $600,000 worth of pineapples and citrus fruits per year, which is the product of between 200 and 250 shippers. Most of these shippers represent individuals or companies. There are only one or two local exchanges. The Porto Rico Fruit Exchange employs a representative to look after the shipping of its fruit in San Juan, and a dock superintendent in its employ receives the fruit in New York, examines it, and if necessary has it repacked. An office is also maintained near the fruit auction rooms in New York City. To these auction rooms samples of each brand in the shipments are taken, and from these samples the whole shipment is sold. Steamship companies segregate all brands, sizes, etc., on the wharf where the buyer takes charge of his fruit. By this system of organized marketing the fruit growers of Porto Rico have been able to bring up the standard of their pack, to purchase in large quantities packing material and fertilizers, and to raise the price from a point that barely covered the cost of production to a standard that makes a good profit in the industry.

CANNED PINEAPPLES.

There are about half a dozen or more plants engaged in the canning of pineapples in Porto Rico (Pl. VIII, fig. 1). Those at the western end of the island are putting up the Cabezona variety, which is being grown for canning purposes. They also can the Red Spanish, but this variety is put up chiefly near San Juan. The style of pack is somewhat different from that of Hawaii. Some of the canneries make

a specialty of fruit for confectioners' trade. For this purpose the pineapples are gathered before they are thoroughly ripe, and while the fruit is quite white in color. Some of it is put up without sirup. The small size of the Red Spanish, especially as the best of the fruit is likely to be shipped fresh, makes it impossible to put up a large percentage of the pack in the highest grade of sliced fruit. Many of the quite small fruits are used to put up crushed, grated, pie-grated, and other forms.

The prices which it is necessary to pay for fresh fruit are much higher than in Hawaii. The success of the fresh-fruit trade brings about this condition of affairs. The table below indicates the prices paid and the classification of the fruits.

Classification and prices paid in Porto Rico for Red Spanish pineapples for canning.

Size.	Approximate weight per fruit.	Range in price per ton. 1913	Range in price per ton. 1914
	Pounds.		
14's	5.1	$20 to $25	$24 to $31
18's	4		
24's	3		
30's	2.4		
36's	2	10	12 to 15
42's	1.7		
48's	1.5	5	5 to 10
54's	1.3		
60's	1.2		

In some canning establishments a somewhat different method of classification has been followed, and in some instances fruits weighing less than 1.5 pounds are not accepted.

It will be seen that 30's, or fruits weighing 2.4 pounds each, are accepted as first grade, while 36's, 42's, and sometimes 48's go as second grade. Some of the canneries will accept 60's, or fruits weighing only 1.2 pounds each, at a reduced price. It will be noted that for the first grade of fruit in 1914 the prices paid were from $24 to $31 per ton. In some cases this fruit was delivered at the cannery and in other instances to the railroad, the buyer paying the freight. The second grade sold for from $12 to $15 per ton. These prices were considerably in advance of those of 1913, when first grade sold for $20 to $25 and second grade for $10. In some instances all fruit from 48's to 14's was taken in 1913 at a uniform price of $22 per ton.

It will be noted that these prices are higher than any that have been paid in the history of the canning industry in Hawaii, and they exhibit a strong upward tendency simultaneously with the complete demoralization of prices on fresh pineapples in Hawaii, where they

sold as low as $5 per ton for first-grade fruit. No attempt is made here to explain this wide divergence in prices of raw material. The canned product from Porto Rico sells (at retail) at somewhat lower prices than that from Hawaii.

PINEAPPLES IN CUBA.

Cuba ships about a million and a quarter crates of pineapples per year, the size of the crate being the same as that used in Porto Rico. A striking contrast between the Porto Rican and Cuban industry lies in the fact that there are many small growers of pineapples among the Cubans themselves. The cultural methods are similar to those pursued in Porto Rico, and the soils likewise vary from sandy to loam. The Red Spanish is the predominating variety, but a few Cayenne are shipped, chiefly from the Isle of Pines. The Abachi (Abakka) is frequently found in the home markets and is popular because of its fine flavor and texture, as well as its attractive appearance. This is a conical-shaped fruit and has the striking character of ripening before the fruit has turned yellow. If kept, however, a very fine color appears before the fruit has become too ripe for use. This variety sells in the Havana market at higher prices than the Red Spanish.

Practically all the Cuban crop is shipped as fresh fruit except the portion which is so consumed at home. There is very little organization of the pineapple growers for marketing purposes, which results in low prices and demoralization of the markets. Much of the packing is also poorly done, without sufficient curing of the fruit, or care in its handling. Fruits are often brought from the field to the packing house in bulk on large bullock carts without springs (Pl. VIII, fig. 2), which, in itself, would cause enough bruises to account for the very heavy losses which are often sustained through decay in transit.

There appear to be large possibilities for the development of the pineapple industry in Cuba. The areas of available land at comparatively low prices, the proximity to the great markets of the United States, together with the location of the island with reference to the routes of travel to Europe, all are favorable to a large development. The cost of labor is higher than in Porto Rico.

PINEAPPLES IN FLORIDA.

The output of pineapples from Florida is quite variable. It has exceeded a million crates in a single year. During 1914 it is doubtful whether the shipments amounted to more than a quarter of a million crates. This shrinkage is to be accounted for by the severe frosts of the preceding winter. Florida appears to be so well adapted to

FIG. 1.—CITRUS ORCHARD WITH PINEAPPLE INTERPLANTING IN PORTO RICO.

FIG. 2.—VIEW IN A 20-ACRE AVOCADO ORCHARD IN FLORIDA.

FIG. 1.—A PINEAPPLE CANNERY NEAR SAN JUAN, PORTO RICO.

FIG. 2.—A BULLOCK WAGON DELIVERING PINEAPPLES IN BULK AT THE PACKING HOUSE IN CUBA.

other horticultural crops—such as grapefruit, oranges, and early vegetables—that the production of pineapples may not be greatly extended.

The pineapple industry of Florida is divided into comparatively small holdings, by far the larger portion of the crop being grown by individuals or small companies. Practically the entire output is shipped as fresh fruit, the canning trade being almost negligible in this State. Some of the pineapples shipped fresh from Florida, as well as from Cuba and Porto Rico, find their way into the canneries of the United States, notably in the neighborhood of Baltimore.

The pineapple area in Florida is confined chiefly to a comparatively narrow zone along the eastern coast line of the southern part of the State, centering about Fort Pierce. The soils are almost pure sand, with a small admixture of humus. These soils, when heavily fertilized, produce very fine crops of pineapples. The arrangement and spacing of plants is much the same as that described for Porto Rico. The bed system is quite frequently found.

The Red Spanish is almost the universal variety and seems well adapted to the soils and conditions of that region. The variety Abachi, mentioned above, is grown to some extent, and skillful shippers succeed in placing it safely in the northern markets, although it is much more susceptible to injury in transit than is the Red Spanish.

Among diseases and insects in Florida may be mentioned wilt and the pineapple scale and mealy bug. Wilt has been quite prevalent and has caused heavy losses. The means for controlling the mealy bug and scale are similar to those mentioned in the discussion of the Porto Rican industry. It was found that some growers were protecting their fruits from sun scald by covering them with small pieces of cotton or other rough material where they had broken over and were lying exposed to the sun.

The fruit is shipped in crates of the same size as those mentioned above and goes chiefly to the large eastern markets, but is sometimes found as far west as San Francisco. There is not the organization of pineapple growers for the marketing of the crop that is found in the case of the citrus growers of the State, who are well organized. Many of the pineapples are shipped through commercial firms in Jacksonville. Florida, although nearer the great markets, is said to have a disadvantage in freight rates, the charge, for example, being 48 cents per crate from Miami to Cincinnati, while from Havana to the same destination it is only 29 cents. The Florida fruit has a long haul by rail before it reaches the market, but it is packed and handled so much better than Cuban fruit that the profits have probably been greater in Florida than in Cuba.

SUMMARY OF OUTPUT OF FRESH PINEAPPLES IN COUNTRIES VISITED.

In round numbers the output of fresh pineapples in the countries visited may be summarized as follows:

	Crates.
Florida	600, 000
Cuba	1, 250, 000
Porto Rico	650, 000
Total	2, 500, 000

Estimated on a basis of 72 pounds per crate, the total crop would be about 90,000 tons. The output of Hawaii in the form of canned pineapple for 1914 was approximately 2,250,000 cases or about 90,000 tons. The fresh fruit export of Hawaii amounts to only a few thousand tons. Florida, Cuba, and Porto Rico sell as much fresh fruit as Hawaii sells in cans.

CITRUS FRUITS.

The citrus industries of Porto Rico are rapidly increasing in importance. The grapefruit has made the most rapid advance, increasing in value from a little over $7,000 in 1907 to nearly $752,000 in 1914, when it equaled the orange output and at the present rate of development will soon surpass it. Porto Rico seems to be peculiarly adapted to the growth of this fruit, the trees bearing abundantly and the fruits, when well grown, being equal in quality to any of those with which they come into competition and superior to many. The business is as yet young, and although handled in a modern manner, many advances in methods of cultivation and marketing will doubtless be made.

Oranges grow on almost every finca, or farm, where they have been planted for coffee shade or for fruit production, but have received, in many cases, little or no attention. These are the seedling oranges which are in the local markets during a large part of the year, coming first from the lowlands and later from the altura, or high country. Late in the winter these fruits become well colored and are excellent for domestic consumption. Considerable shipments of these are also made to the United States, where in seasons of high prices they bring enough to pay a small profit to the shipper. The methods of handling these oranges, however, are far from satisfactory, since the growers are wholly unfamiliar with commercial methods of culture, handling, and packing.

Probably the larger part of the oranges shipped from Porto Rico is grown in orchards and handled in as modern a manner as could be expected in the early stages of the development of the industry. These orchards, budded to commercial varieties, are owned and con-

trolled by Americans almost exclusively. The Porto Ricans themselves have not adopted this type of cultivation.

The lemon is not produced in Porto Rico to any considerable extent, although there are some trial plantings on the south side of the island. The orchards of oranges and grapefruit just referred to are along the north side of the island in much the same localities as the pineapple.

In methods of cultivation there are some other points which are worthy of notice. The use of cover crops is notably on the increase, the jack bean (*Canavali ensiformis*) having proved of great value there, as it has in Hawaii. At most seasons of the year in the citrus districts there is an abundance of rain to maintain the trees, and the cover crop, which prevents the soil from washing, adds nitrogen, and maintains the supply of humus. In some cases grass has been allowed to grow under the trees, and some growers claim that the results have been very satisfactory.

The prevailing winds necessitate permanent and effective windbreaks, and one of the striking aspects of the landscape is the windbreak of bamboo about these orchards. Under Porto Rican conditions, the bamboo lends itself well to this use, making a rather thick mass of foliage through which the wind sifts slowly.

Porto Rico appears to have a comparatively easy task in the control of scale insects which add so much to the expense of citrus culture in many parts of the world. Nearly all the common scale insects of citrus are found in the island, but most of them are held well in check by fungi. The red fungus (*Sphærostilbe coccophila*), the gray fungus (*Ophionectria coccicola*), and several species of black fungi are found to hold the scales under control. The relation of windbreaks to the control of insects by fungi is important. In exposed places, the fungi do not prosper sufficiently to be an effective means of control. The windbreaks, therefore, serve a double purpose in protecting the trees from wind injury and in assisting the warfare against insects. It is not generally found necessary to distribute these fungi by spraying or other artificial means. The attempt is being made to introduce these beneficial fungi into Hawaii. It is not to be expected that they will prove as effective in the dry climate of Honolulu, but in many humid localities, such as Hilo, Puna, and the Kona district of Hawaii, it is not improbable that these fungi would be a great aid in controlling the purple scale and the Florida red scale, which are so prevalent in these islands.

Aleyrodes howardi, related to the white fly (*A. citri*) which has given so much trouble to the citrus growers of Florida, is found in Porto Rico and is said to be a native species. It affects the orange, as well as a long list of other plants, but is not of so much economic importance, probably on account of its being parasitized by a hymenop-

terous insect not yet identified. *Pseudococcus citri* is said to be held well in control by the Australian species of ladybird (*Cryptolaemus montrouzieri*).

In Cuba the brevity of the visit made it impossible to do more than take a passing glance at the citrus development which has taken place in recent years. There are a great many small citrus holdings and a number of very large plantations of oranges and grapefruit, considerable American capital having been invested in that island. There is a large local consumption of oranges, many of these being shipped to the markets of Havana and the other large cities of the island. The larger part, however, is shipped to the United States. Because of the almost unlimited extent of land available at comparatively low prices, and because of the proximity to the American markets, there appears to be opportunity for much greater development. Many citrus orchards, however, have been planted and abandoned for one cause or another. Some of these have been on land unsuitable for their culture.

A striking feature in some of the Cuban citrus groves was the presence of grass, which has also been mentioned as having been found, but to a less degree, in Porto Rico. Many growers of citrus trees in Cuba claim that they have obtained better results by this method than by any other which has been tried. Whether a thorough test of leguminous cover crops has been made was not determined.

Scale insects are controlled by the same means as in Porto Rico. In all places visited, fumigation was never practiced, and spraying was used chiefly as a means of controlling the rust mite. This pest is very common and injures a large amount of fruit, which, although not affected in quality, is so badly injured in appearance as to seriously reduce the price. By means of the usual sprays, notably sulphur, the injury can be kept down to negligible proportions.

An orchard wagon of American manufacture seen in Cuba is worthy of mention as being possibly adapted to use in the pineapple fields of Hawaii. The peculiarity of this wagon is that the rear wheels follow exactly in the track of the front wheels. This prevents injury to many plants because not a few drivers who are able to drive well enough to get the front wheels away from the plants, run over them with the rear wheels of the ordinary wagon. Some of the pineapple growers of Hawaii are interested in further investigation of this type of wagon.

The citrus industries of Florida are older and more highly organized than those of Porto Rico and Cuba. The brief visit in this State permitted only a glance at a small part of the industry. Some of the matters which have been mentioned in connection with the citrus industries in Cuba and Porto Rico also impressed themselves

here. The efficiency of the parasitic fungi on some of the citrus scales was apparent. This, together with spraying for certain scales and for the rust mite, has resulted in very clean, bright fruit in many of the groves.

The highly organized system for the marketing of citrus fruits is worthy of special note. The Florida Citrus Exchange handles approximately 25 per cent of the output. The estimated crop for the 1914–15 season was about 7,000,000 boxes, of which the Florida Citrus Exchange probably handled from 1,500,000 to 2,000,000 boxes. This is an organization of producers and has done much to systematize marketing and bring satisfactory returns to the grower. The details of its organization can not be gone into here.

One of the most talked of subjects in citrus circles at the time of the visit was the citrus canker, a disease which had recently made its appearance in two widely separated parts of the State, one area of infestation being in the southern part, in Dade County, and the other in the extreme north, at Monticello, quite close to the Georgia line. This disease affects the foliage, the branches, and the fruits of several species of citrus, being notably a pest of the grapefruit, for the excellence of which Florida has become famous. This disease, which has also been found in most of the Gulf States where citrus is grown, appears to be very difficult of control. The energetic manner in which the growers and the Government are attempting to eradicate the disease from Florida is noteworthy. The warfare has passed from the stage of spraying and even of cutting down whole orchards to the use of an oil-burning torch especially constructed for the purpose. It was found that by the cutting down of the trees the operators themselves spread the disease. The torch is now applied without the operators coming in contact with the trees. So vigorous is the warfare that every tree that shows the slightest infection is burned to the surface of the ground. The soil also is treated in like manner. Whatever may be the outcome of the struggle, no efforts are being spared to rid the State of this serious disease.

The overhead systems of irrigation which have been installed in some citrus orchards attract attention. These have proved valuable not only as a means of supplying the trees with water but also in fighting frosts. The application of an artificial shower to the trees is a very decided protection during cold nights. Many growers feel that the system is worth all that it costs, either as a means of irrigation or protection against frosts.

Florida has been somewhat prolific in varieties of citrus fruits. A new orange, known as the Lue Gim Gong, which originated at De Land, is attracting much attention at the present time. Its special merit appears to be in its holding firm to the tree after it has

become ripe and well colored. It is said that it will hold on the tree for a year or more, enabling the grower to extend the shipping season for his fruit. It is described as "a late round orange of unusual merit."

Another of the originations of Florida now coming into some prominence is the Foster grapefruit, said to be a bud mutation from the variety Walters, which it very closely resembles in all particulars, except that the Foster has pink flesh, a new feature among the pomelos grown in the United States or the West Indies. Both of these varieties are now growing in Hawaii, and a limited supply of budwood will soon be available.

THE AVOCADO.

The avocado is claiming a place of considerable commercial importance in Florida and in California, but the West Indies do not appear to have awakened to the possibilities of profit in this unusual fruit. In Florida there are orchards of 25 to 30 acres, some of them now in bearing, while new plantings are constantly being made, particularly in the area along the east coast from Palm Beach southward (Pl. VII, fig. 2). The natural limitations of successful culture have not yet been determined, and there appears to be less tendency to emphasize the hardy varieties than in California. The avocado does not appear to be lacking in vigor and productivity in the parts of Florida referred to. This State possesses an unusual advantage in its proximity to great markets where its fruits can be placed about two days after picking, thus avoiding the need of refrigeration. The Trapp is the leading commercial variety and has many points in its favor, being in season when the markets are no longer glutted with northern fruits, and having a good form for packing and good keeping qualities. It is one of the easiest varieties to bud. The methods of budding are essentially the same as those which have been found adapted to conditions in Hawaii. In general practice, the bud is tied with only a waxed bandage which remains in place about 17 days, after which the bud is forced into growth by cutting back a few inches at the top of the stock and later removing its buds as they start into growth. There is a strong tendency to bud stocks in shingle boxes or other containers rather than in the nursery row, due in part to the Florida soils being not suited to the practice of lifting nursery plants with a ball of soil.

Porto Rico is rich in very excellent varieties of avocados, or aguacates, as they are known there and in other Spanish-speaking countries. The lack of effort to propagate by budding may be due in part to the high average of excellence among seedlings, but more probably to the fact that the commercial possibilities of this fruit

have not yet been recognized. With a three or four day service direct to New York, a season that could be made to cover nearly the entire year, varieties that need only to be sought out, standardized, and propagated by buds, and a climate in which the conditions are ideal and the danger of frost unknown, there appear to be opportunities that would appeal strongly to the enterprising fruit growers of California or Florida. The American fruit grower in Porto Rico is busy establishing his citrus and pineapple industries, which are yet young, and the native Porto Rican has not taken very enthusiastically to any line of fruit production.

Porto Rico doubtless has some varieties worthy of introduction into Hawaii, particularly choice early and late sorts to lengthen the season. This could be done at the present time by searching out the seedling trees, but when Porto Rican varieties have become standardized, it will be an easy matter to make the introductions by means of budwood which may be safely carried through the mails.

In Cuba, the price of avocados in July was a striking feature. Good-sized fruits were selling in Havana at 20 to 25 cents Spanish money,[1] and exceptionally good fruits are said to bring 10 cents each even in the height of the season. In the country districts, it was found necessary to pay 5 cents each for ordinarily good fruits in July, which, while not mid season, can not be regarded as out of season. It is said that they become quite cheap for a short time when they are most abundant.

There appears to be very little commercial culture of the avocado in Cuba, but interest in it is beginning to be aroused. The very large consumption of the fruit in Havana itself and the proximity to the American markets, with direct and frequent transportation, would seem to indicate that there are possibilities in the culture of the avocado here which will grow in importance as the fruit comes to be more widely known and used.

California is probably planting avocados more rapidly than any other country at the present time, plantings being made in different localities from San Diego to Butte County. In this State much emphasis is being placed upon hardy varieties, some of which are claimed to endure as much cold as the orange. These have been introduced chiefly from the highlands of Mexico. Some seedlings from Hawaiian stock were considered hardy under ordinary conditions, but many of these were unable to endure the severe cold of the season of 1912–13, when they were killed to the ground in the nursery.

In California budding in the open nursery is growing in favor, and in the heavier soils of this State it is possible to " ball " the trees

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[1] The Spanish dollar has a purchasing power of something over 90 cents American money.

for transplanting. Many new varieties are being described and propagated, and there is considerable diversity of opinion as to which of these varieties are likely to take permanent places in the avocado culture of the State.

Concerning the insects and diseases of the avocado in the countries visited, some facts were noted. The avocado mealy bug (*Pseudococcus nipæ*) was found in a city park in Mayaguez, Porto Rico, but was not seen elsewhere, and so far as could be determined, it had not been reported in the entomological records of the island, which would make it appear to be a comparatively recent introduction. The same species was found in one of the orchards in south Florida, but elsewhere was not seen, and appeared to be unknown to avocado growers, indicating that it is probably a recent introduction in Florida also.

No avocado borer (*Xyleborus* sp.) was seen or reported in any of the countries visited. The larva of an insect, locally known in Cuba as the bagworm, is said to eat the foliage of the trees. It is not reported as a very serious pest. Red spiders appear to be generally distributed and do slight injury, as in Hawaii. A disease first affecting the roots but later involving the trunk also, was reported in Cuba and was said to be somewhat serious. It was not seen and its identity has not been learned.

THE MANGO.

The mango has been planted on a commercial scale by at least one company in Porto Rico. The trees are vigorous and some varieties bear abundantly. The problem of determining the varieties best suited to local conditions is now being worked out. These have to be selected with reference to several factors, notably, varietal resistance to the mango fruit fly and to the mango blight. The mango fly (*Anastrepha fraterculus*) is similar in habit to the Mediterranean fruit fly, with which every one in Hawaii is now familiar. Varieties show marked differences in resistance. The Sandersha, for example, which is one of the largest and finest in appearance, as well as a most prolific bearer, is also one of the most susceptible to the fly.

The mango blight (*Glœosporium mangiferæ*) is prevalent in the moister parts of Porto Rico, as in Hawaii, but some varieties are quite resistant. On the dry side of the island, with irrigation, this disease would do practically no injury.

One of the most promising varieties in Porto Rico is Amini, of East Indian origin. It very closely resembles Pirie, is said to be free from the attacks of the fly, and grafts readily on the native stock.

Piña (pineapple) is one of the so-called native varieties and is worthy of some attention. It has very little fiber, is of good flavor, and is quite resistant to the mango fly.

FIG. 1.—CRATES OF MANGOES AS THEY ARE PACKED IN FLORIDA.
Note the three different sizes of crates.

FIG. 2.—A TREE TOP-WORKED TO THE HADEN MANGO.

Hueva del Toro is one of the most common of the Porto Rican mangoes. It is of good appearance and fair flavor, but is somewhat fibrous and extremely subject to the attacks of the fly. It is very similar to the Hawaiian sweet mango.

In addition to several varieties of mangoes that have been introduced by the United States Department of Agriculture, three East Indian varieties have been introduced by the Misses Leitch, of Garrochales, who are making every effort to establish the mango on a commercial basis in Porto Rico. The varieties are known as Champaddan, Colombo Kidney, and Ceylon Horse House. The Colombo Kidney was seen and tasted and proved to be of excellent flavor and very fine texture.

A method of bark grafting the mango has been devised by the Porto Rico Experiment Station and is now being used by a number of fruit growers. This method has been found well adapted to Hawaiian conditions. (See p. 22.)

In Cuba there are a few commercial plantings of the mango and many of the East Indian varieties are being tested. Among the established forms that have long been in the islands, it is interesting to note the points of relationship to those of Hawaii. The variety known in Cuba as Manila is very similar to, if not identical with, that known in Hawaii as Pointed Chutney. It is of delicious subacid flavor and is free from fiber. The Seda is the same as that known in Hawaii as the No. 9, of which there are several forms all tending to the "S" shape and all of mild flavor and rather fibrous texture. Criollo closely resembles the variety in Hawaii known as the Double-Pointed Manila.

Florida has made substantial progress in establishing a mango industry, and small commercial shipments are being made regularly in season. (Pl. IX, fig. 1.) Budding is done in the nursery row and also in pots, and many varieties are being tested. The Mulgoba has been more generally planted than any other and is certainly a very fine mango as grown in Florida, where it acquires a good color. It is said to be a somewhat uncertain bearer, and growers are hoping for much from its seedling, the Haden, which is just now attracting attention and gives promise of being a heavier and more regular bearer (Pl. IX, fig. 2).

The establishment of the mango on a commercial basis is necessarily a slow process, but there can be no doubt of the ultimate outcome in countries adapted to its culture and able to ship the fruits to large markets. The best mangoes appeal to the average taste and are most attractive in appearance.

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HAWAII AGRICULTURAL EXPERIMENT STATION,
J. M. WESTGATE, Agronomist in Charge,
Honolulu, Hawaii.

Under the supervision of the STATES RELATIONS SERVICE,
Office of Experiment Stations, U. S. Department of Agriculture.

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[Under the supervision of A. C. TRUE, Director of the States Relations Service, United States Department of Agriculture.]

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LETTER OF TRANSMITTAL.

HAWAII AGRICULTURAL EXPERIMENT STATION,
Honolulu, Hawaii, July 29, 1919.

SIR: I have the honor to transmit herewith and to recommend for publication a report of the Hawaii Agricultural Experiment Station, 1919.

Respectfully,

J. M. WESTGATE,
Agronomist in Charge.

DR. A. C. TRUE,
Director States Relations Service,
U. S. Department of Agriculture, Washington, D. C.

Publication recommended.
A. C. TRUE, *Director.*

Publication authorized.
E. T. MEREDITH,
Secretary of Agriculture.

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[1] Appointed Apr. 9, 1919, to succeed M. O. Johnson, resigned.
[2] Temporary appointment, Apr. 1 to June 30, 1919.

CONTENTS.

ILLUSTRATIONS.

REPORT OF THE HAWAII AGRICULTURAL EXPERIMENT STATION, 1919.

SUMMARY OF INVESTIGATIONS.

By J. M. WESTGATE, *Agronomist in Charge.*

INTRODUCTION.

During the past year the energies of the station were largely directed to the most pressing problems of production of food for human beings and feeds for animals. This work in part was successfully carried out by the distribution of seeds, cuttings, and plants to individuals and to public institutions. Improved varieties were given wide distribution, up-to-date cultural methods, including spraying for insects and fungus enemies, and other means used to increase crop yields, were received and adopted to a gratifying degree by the producers. Pleasant cooperative relationship was maintained with the Territorial food commission, and especially with its corps of county agents.

The station continued to emphasize the desirability of increasing the production of diversified crops. It is and has long been fully realized that locally grown diversified crops must compete, to a large extent, with crops imported from the coast. These are often imported at less expense for freight than is paid on similar crops from the other islands of the group. In Hawaii the uneven surface of the land usually devoted to diversified crops and the small size of fields necessarily increase the amount of hand labor required, thereby increasing the cost of production. It is felt, therefore, that too great stress can not be laid on the desirability of having many new kinds of crops produced in considerable quantities so that the agricultural practices necessary to the production of these crops on a large scale could be readily adopted in case any calamity should befall the sugar, pineapple, or banana industries.

Tendencies in the island seem to have been the nonencouragement, rather than the encouragement, of production of diversified food crops. This fact is borne out by the recent failure of the Territorial legislature to make an appropriation for the continuation of the agricultural county-agent system, and likewise by their withdrawal of the customary appropriation from the Territorial marketing

division. The latter, during the past seven years, developed from a small beginning to where, in April, May, and June of 1919, it handled $56,249.72 worth of produce and filled a long-felt need for the consumer and small producer. At the time that the county agents were eliminated, provision was made for a sugar-cane expert, at a salary of $500 a month, to advise and assist those raising sugar cane on their homesteads. The Territorial financial support was also withdrawn from the Glenwood substation, it being proposed to transfer the agricultural experimental work of the Territory to the opposite side of the island of Hawaii, where there are larger areas of potential homesteading land suitable for the production of diversified crops. An appropriation was made for the establishment and maintenance of a new station at Waimea, Hawaii; unfortunately, however, the money appropriated was to be supplied from the "loan fund," which, it is claimed, can be used for permanent improvements only and not for the operation of an experiment station. At its last session the legislature authorized the expenditure of $5,000 for farm buildings at the Haleakala demonstration farm. It is planned to construct these buildings in 1920, loan funds having been provided for that purpose.

Although the Territorial legislature saw fit to withhold its support from the Territorial county-agent system, it is universally acknowledged throughout the islands that this method, as developed during the war period, thoroughly demonstrated its efficiency in bringing home to the mixed population of the islands those improvements in agricultural practices deemed desirable for general adoption. The personal contact of the county agent with the tiller of the soil is the most effective means of solving the many difficult problems confronted by the producing classes. It is hoped that subsequent Territorial legislatures will reestablish the Territorial county-agent system to supplement the Federal extension work at present under way.

COOPERATIVE ACTIVITIES.

It has been the policy of the station to undertake work in cooperation with individuals, institutions, and organizations, both public and private, wherever the work in question promised to be of mutual advantage. It was felt that by giving careful attention to the formulation and execution of plans, many projects could be as effectively carried out through the cooperation of such an agency as though the station unaided had undertaken the entire work. Such cooperation would make it possible to provide for many more projects than can be cared for when the entire cost of the work is borne by the station alone.

As specific instances, it should be noted that the station continued to cooperate with representatives of the several military posts

throughout the islands, and provided seeds and plants for gardens of the various companies. These gardens, which proved a very valuable adjunct to the needs of the local military establishments, were looked after by specially detailed men from each company, the work usually being assigned to those who showed a decided liking for it. Prizes won at the last two Territorial fairs indicate, in some measure, the success achieved in vegetable raising by the gardeners. The products from each company's garden formed a most welcome addition to the standard Army rations, and, in some instances, the attempts to farm proved so successful that the supply of products obtained exceeded their demand.

The station established an increasing number of cooperative relations with small farmers, and with a number of the larger ranches and plantations. The small grower was provided with such seed and planting material as was found practicable, and all possible information and assistance necessary to further any particular line of his work was furnished him. With larger concerns, the station usually confined its efforts to giving expert advice and assistance in outlining those experiments carried out by the men in charge of the ranch or plantation. Since these experiments sometimes extend over a number of years, those having their immediate oversight must carefully follow them up until the results of a number of seasons have been obtained. It was found, owing to the great diversity in rainfall, altitude, and soil conditions, that experimental results true of one locality may not be true of another, even though separated by only a few miles. For this reason it was desirable to repeat, in the immediate localities where work was to be tried out on a larger scale, those experiments which were successfully carried on by the experiment station. These repetition trials are ordinarily conducted in cooperation with private parties, it not being felt that continual close supervision on the part of the station is as essential as is the case with the regular station experiments.

In addition to the above-mentioned cooperation, the station maintained relations with agricultural societies, chambers of commerce, business men's clubs, and with the trustees of several large estates who are broadly interested in the development of diversified agriculture. The Hawaiian Sugar Planters' Experiment Station, and some of the pineapple, sugar, and banana plantations proved very helpful in a number of cooperative undertakings.

Informal cooperative relations also existed between this and various State experiment stations, and with the several branches of the United States Department of Agriculture at Washington, as well as with the agricultural departments of many foreign countries.

NEED OF SUPPLEMENTARY FOOD CROP INDUSTRIES.

The Hawaiian Islands depend entirely too much upon the sugar industry for their true prosperity, and there is always the possibility that the market price of sugar may fall to such a level that many of the plantations would be forced out of business. There is further a strategic need for the growing of other crops, so that these islands may be less dependent on the outside world for their food. It was, therefore, considered as especially desirable that the development of diversified industry be either in the actual production of food crops or, at least, in the production of agricultural products from which foods can be prepared. In normal times these crops would be available for export either in the raw or manufactured state, and, during a time of blockade or interruption of communication, they could be readily used to feed the local population.

With this end in view, various root and tuber crops were grown for their starch production, and the process of drying and preserving vegetables and fruits received careful attention from many of the station workers. F. G. Krauss, superintendent of the extension division, in company with a representative of one of the local agricultural companies, made a trip of inspection and investigation to the mainland for the purpose of furthering this work and in order to determine market possibilities, methods of manufacture, etc., covering the starch production industry. A large part of the United States was covered, investigations being made in States as widely separated as California, Massachusetts, and Florida. The experiment station and the extension division were primarily interested in this project not only for the above reasons, but because it promises to furnish additional means of livelihood for the small farmer; furthermore, after the starch has been extracted, the residual product can be made to serve as a valuable constituent of mixed feeds for live stock which now depend to a great extent upon imported feeds.

Preliminary investigations made with cassava and edible canna indicate that a profitable industry can be developed. Yields of cassava as high as 16 tons per acre, and of edible canna at the rate of 40 tons per acre, under ideal conditions as to soil fertility and moisture supply, further this possibility when one realizes that about 10 per cent of the edible canna and 25 per cent of cassava is commercially extractible starch. Cassava starch can be used commercially in sizing cotton goods, in the preparation of certain forms of adhesives, and as the source of tapioca. Because of its extraordinarily large starch grains, the edible canna has been declared superior to arrowroot starch for invalids; and it is thought that this product will, as a result, command a price sufficient to make its continued production profitable

In its further search for additional potential industries, the station devoted some time and attention to the development of methods of manufacturing various fruit and vegetable products, such as dried bananas, pickled fruits and vegetables, guava jelly, vinegar from pineapple waste, candies made up on a foundation of macadamia nuts, and the preservation of the avocado.

THE SECOND ANNUAL TERRITORIAL FAIR.

The success of the first Territorial fair, held in June, 1918, was due in large measure to enthusiasm developed by the war. While the second fair, held in June, 1919, did not receive the same stimulus, very effective work, surpassing that of the previous fair was accomplished by the county agents and other committeemen. The results of the agricultural extension work were manifested in the variety and quality of the agricultural exhibits shown. Among the exhibitors, keen competition was fostered by awarding cash prizes to those who displayed certain crops in which it was desired to arouse interest for their further development.

The second Territorial fair cooperated so splendidly with the experiment station in setting forth the desirability and possibility of diversified crop production that every available resource was temporarily devoted to bringing to a successful close those particular activities for which the station members had been made responsible by the fair commission. Each division of the station was represented by special exhibits, and most of the station staff held one or more committee assignments in connection with the various agricultural features of the fair. Acquaintances made during the food production campaign of the war period were turned by the station to its best advantage in developing enthusiasm among the various exhibitors.

The domestic science exhibits specialized on economical menus rather than on wheat and fat substitutes; the Japanese committee made a most creditable showing of numerous Japanese foods, daily changing its exhibits. The exhibit by the sugar plantations, of various industries which are receiving attention from them, was most commendable. One company exhibited the work of making cement from nonimported materials, and also demonstrated the practicability of obtaining from waste cane molasses a fuel which can be substituted for gasoline. Another plantation made an extensive exhibit covering its development of home-grown feeds for all classes of live stock. Among three exhibitors there was keen competition regarding mixed feeds which contained 50 per cent or more of home-grown products, such as pigeon-pea meal, velvet-bean meal, alfalfa meal, cane-top hay, waste molasses, cracked corn, etc.

HORTICULTURAL INVESTIGATIONS.

One of the more important features of the work of the horticultural division was that of the extension of Macadamia nut growing. About 1,000 seedlings were planted at various elevations throughout the islands. The few isolated old plantings of the Macadamia tree clearly indicate the chances of the successful production of this nut in the Hawaiian Islands.

Work with the avocado made material progress, and it is hoped that a greater interest can be aroused among growers to improve the many varieties of this fruit. Several small cooperative commercial orchards were started mainly to demonstrate the possibilities of the commercial production of the avocado. Sixteen new varieties of the Guatemalan type were received from the United States Department of Agriculture at Washington and planted for observation.

The station not only demonstrated varieties of mango best suited to conditions of the islands, but also started propaganda to further development of the superior strains. As a result numerous seedling trees throughout the islands were top-worked with improved strains, especially the Pirie, upon which the station is concentrating a good deal of attention.

The Solo papaya, which was under test, has proved to be a very promising strain. It has been brought to the fourth generation without deterioration in flavor or other desirable characteristics.

Investigations with the litchi tree were continued, and great prospects are looked for from the propagation of this exquisitely flavored fruit.

Considerable attention was also given to the coffee industry, which, owing to the prevailing low price of the coffee berry, is not in a flourishing condition.

Work with the propagation of pineapple seedlings was uninterrupted, and several thousand young seedlings were planted in commercial pineapple fields of different localities. A few of these are already beginning to bear fruit.

CHEMICAL INVESTIGATIONS.

One of the major projects of the division of chemistry throughout the year was that of drying and preserving Hawaiian vegetables and fruits. By the use of a drier, the working model of which was constructed on the station grounds, various tests were conducted with many island foods which were found adapted to preservation by drying. This drier, which is independent of weather conditions for effective results, is much more rapid in its action than the air drier, which was also kept in operation. By the use

of the small vacuum drier, exact data, showing rate of loss of moisture of the various crops, is readily had. This vacuum drier has also made it possible to obtain a better product of bananas and similar fruits, since the temperature and air pressure can be regulated and determined with much greater exactness than by other methods used.

The drying and preservation of fruits and vegetables, and the production of starch from cassava, edible canna, sweet potatoes, corn, taro, etc., have opened up commercial prospects which are receiving investigation from the experiment station and from various commercial interests of the islands.

AGRICULTURAL EXTENSION WORK.

The extension division, which has kept in close touch with the various agricultural projects of the islands, endeavored at all times to develop the most practical solutions of the many problems continually arising. The headquarters of the superintendent of the extension division are located at Haiku, on the island of Maui. The installation of an efficient telephone service has made it possible for him to keep in touch with the more remote and relatively inaccessible sections of the island.

Lectures, together with voluminous correspondence, and some practical demonstrations of caponizing, home curing of pork, etc., were effective in reaching large numbers of individual farmers. The promising showing made by the pigeon pea, edible canna, and cassava, justified the appeal made by the extension division to increase the production of these crops. Every assistance was rendered home and school garden activities, and some efforts were put forth to include corn clubs, calf clubs, etc., and to further the general development of this work. A pig club was recently launched on the island of Maui, the formal organization taking place in July, 1919, with about 31 enthusiastic young people in attendance. Steps were also taken to establish a farm bureau in each of the leading agricultural sections of the islands.

Nine collaborators were associated with the division during either the whole or a part of the year, one or more being located on each of the five larger islands. During the year the superintendent of the extension division made a trip to the mainland to investigate problems of production, utilization, and marketing of such starch crops as cassava and edible canna, and to determine at first hand the latest development in extension work.

On the island of Hawaii the extension work was materially furthered by the appointment on April 1, 1919, of R. A. Goff as director of extension for that island.

At the Haiku demonstration and experiment farm the best adapted varieties of both new and staple crops were demonstrated, and seed and planting material of these superior varieties were distributed to the farmers throughout the islands.

PLANT-DISEASE INVESTIGATIONS.

The division of plant pathology continued work to develop practical methods for overcoming diseases which infest the standard food crops of the islands. The major portion of the pathologist's time was taken up with investigations of the taro rot and the banana freckle disease. The banana freckle disease, which now threatens the entire industry, is a serious malady which first came under observation in 1917. Experiments carried on in cooperation with one of the leading banana growers resulted in the systematic spraying of a 75-acre field, which is now giving very promising results. An interesting series of observations was made on root rot troubles of bananas, pineapples, and sugar cane. So far these have yielded nothing sufficiently definite to justify publication at this time.

In addition to those reported on in previous annual reports, further miscellaneous plant diseases were observed and recorded.

AGRONOMIC INVESTIGATIONS.

During the year the agronomic activities of the station were concerned primarily with the most practical means of rapidly increasing the production of food and forage crops. This was brought about by the extensive distribution of seeds, cuttings, and tubers to all who had proper facilities for growing them. As soon as it became evident that the end of the war was near, the work of the division gradually shifted from the routine work of stimulating production to the improvement of those crops the standard varieties of which were already very well established throughout the islands.

Both the Guam and the Cuban Red corn have made splendid growth, though the former has given consistently higher yields on the station plats than the latter. However, the Guam variety, because of its white color, is locally at a disadvantage, inasmuch as the market favors a yellow variety of corn. Plans were, therefore, formulated for hybridizing the Guam corn with a variety of the desired color in the hope of combining the leaf-hopper resistant and other good qualities of the Guam corn with the yellow color demanded by the local market. It is considered more practicable to try to change the color of a variety of corn rather than to try to overcome the intense local prejudice of the several races against corn of a shade other than that to which they have long been accustomed.

Experiments with the sweet potato, one of the standard food crops of the island, were carried on to develop strains superior in

yield and possessing excellent market and table qualities. Great variation has already been noted in the seedlings which owe their origin in part to hybridization.

The station plats of edible canna and cassava have clearly demonstrated the value of these two root crops, and liberal distribution of these as planting materials were made.. Fertilizer tests have given additional information regarding requirements of these particular crops under island conditions.

The work of the Castner substation was continued and, at the request of the Army authorities at Castner, a planting plan was prepared and submitted for the utilization of the species and varieties found to be most promising. Several days were spent by the agronomist in charge of the experiment station in locating a suitable site on the reservation for planting the more promising varieties on a much larger scale than was practicable at the Castner forage-crop substation.

POULTRY INVESTIGATIONS.

During the latter part of the fiscal year 1919 the station was fortunate in securing the temporary services of a poultry expert, L. M. Ross, who brought to completion a brief survey of poultry conditions in the islands. At present the most pressing problems with poultry are adequate housing, the provision of sanitary surroundings, and the proper methods of feeding, including properly balanced rations. It was found practicable to materially reduce the proportion of imported concentrates in the diet for island-raised poultry. Most of the poultry work of the station was conducted at the Glenwood substation on the island of Hawaii, but the present undertaking shows the need of conducting work on each of the larger islands.

GLENWOOD SUBSTATION.

The work of the Glenwood substation was directed largely to poultry and food crop production. The eggs were used for hatching purposes throughout the islands, and the surplus roosters were made available for breeding purposes. Experiments carried out in the past proved conclusively that potatoes, beans, cabbage, corn, and alfalfa can be successfully produced under Glenwood conditions, but that other standard crops are not ordinarily practicable. Among the successful minor crops were pohas, sorghum, edible canna, and pigeon peas. During the year 12 demonstration plats of alfalfa were established on the eastern side of the island of Hawaii. In many instances where very young seedlings were devastated by cutworms it became necessary to transplant the well-grown seedlings to fields. This was a laborious and expensive undertaking,

but the method will have proved a practicable one if the stands maintain themselves for a number of years.

In addition to attending to his regular duties at the Glenwood substation, the superintendent did considerable extension work in the immediate vicinity of the substation. In this matter it was found practicable to cooperate with the Territorial food commission and its county agents. The district immediately surrounding the Glenwood substation was taken over by the superintendent, who acted as its county agent. The remainder of the island of Hawaii was divided between the two Territorial county agents.

Ever since the establishment of the Glenwood substation the Territory has appropriated most of the money required for its maintenance. The 1919 session of the Territorial legislature, in response to the demand for the establishment of a similar station on the opposite side of the island, transferred its financial support to the prospective Waimea substation. However, it is planned to continue the Glenwood substation without financial support from the Territory, using such Territorial equipment as will not be required at the new station. The Glenwood substation will be run largely as a demonstration station and carry on such experimental work as can be provided from the funds at hand.

CHANGES IN THE STATION STAFF.

During the year there were a number of changes in the station staff. Maxwell O. Johnson, chemist, resigned March 20, 1919, to accept a position as industrial chemist with the Pearl City Fruit Co., Pearl City, Hawaii, at a large increase in salary. He was succeeded by Wallace Macfarlane April 9, 1919. H. L. Chung, assistant in agronomy, was absent in military service from October 15, 1918, to December 10, 1919, inclusive. R. A Goff, superintendent of the Glenwood substation, was appointed extension agent for the island of Hawaii on April 1, 1919. Temporary appointments were given L. M. Ross as poultry expert April 1 to June 30, 1919; E. J. Mooklar, assistant in fruit and vegetable utilization, November 25, 1918, to February 20, 1919; and P. L. Hesketh, assistant in market garden investigations, March 1 to May 31, 1919.

REPORT OF THE HORTICULTURAL DIVISION.

By J. Edgar Higgins.

The activities of the horticultural division were considerably affected during the year by war conditions. James H. Cowan, assistant in horticulture, who left to enter military service, almost immediately upon his return to the station on July 1, 1919, accepted

a position with the College of Hawaii as custodian of grounds. In the meantime no assistant in horticulture has been appointed. P. K. Lee, however, has rendered very valuable assistance in propagation work, in keeping records, in mapping permanent plantings, and in looking after much of the detail work.

While waiting further assistance an attempt was made to sustain, as far as possible, the line of work under way before the war started. Some attention was given to the Macadamia, or Queensland, nut as the basis of a possible new industry; and, on a trip to the island of Hawaii. certain phases of the coffee industry were investigated.

MACADAMIA NUT.

The Macadamia, or Queensland, nut (*Macadamia ternifolia*) (Pl. I, fig. 1), is one of the most promising of all nuts for improvement and for commercial cultivation within the Tropics or subtropics. It has received little attention, however, and in fact has been almost wholly neglected, notwithstanding the fact that it is unexcelled in richness and delicacy of flavor. This is one of the many obscure tropical products which should be brought to light, improved in some respects so as to be better adapted for commercial use, and thus be made to play an important part in feeding the world.

The tree is of upright growth, attains a height of probably 35 feet, has dark green foliage and rather dense head, and begins to bear when from 5 to 8 years of age. The nuts, which are incased in a hard shell one-eighth inch thick, are brown in color and about $1\frac{1}{4}$ inches in diameter. The kernel is perhaps three-fourths inch in diameter, nearly spherical or slightly flattened, white, and of a delicious flavor. It resembles the Brazil nut but is regarded by many as milder and more pleasing.

The trees of this species vary greatly in respect to productivity, size of nut, character of foliage, and bearing age. This is one of its splendid features, and gives rise to hope for great improvements by selection. One of the first changes brought about should be a softening of the shell, which is hard and thick. This feature probably is highly responsible for the failure of the nut to be more widely recognized and disseminated.

In a letter from Prof. Albert H. Benson, director of fruit culture for the department of agriculture of Queensland, it is stated that the thickness of shell varies considerably among the trees in their native conditions, and his observations have led to the conclusion that had the question of improving this nut been seriously taken in hand a comparatively thin shell would have eventuated ere this.

Another direction for selection and change is suggested by the fact that many of the seedlings have foliage possessing strong, spiny

teeth, while others are nearly free from this objectionable feature. Although the spiny character is not so serious a matter in a nut tree of this nature as in a tree from which the fruits must be gathered by hand, it is important nevertheless to eliminate such an undesirable feature. The spines greatly interfere with the comfort and convenience of the operator when pruning, spraying, and budding.

The experiment station is endeavoring to extend the trial of the Macadamia nut tree for propagation and permanence in Hawaii. This tree was introduced into Hawaii many years ago from Queensland by Messrs. E. W. and R. A. Jordan, the latter of whom secured the seeds in their native land. Specimen trees are to be found to-day in several parts of Honolulu and throughout the islands. The trees have prospered under the conditions in which they have been tried in Honolulu, and a few which bear each year are growing on the experiment station lands on Mount Tantalus, at an elevation of about 1,000 feet.

The division of horticulture grew about 1,000 trees from seeds collected at the Tantalus gardens, and kept them in readiness for planting during the summer of 1918. The station received the hearty cooperation of the trustees of the Bishop estate, and Mr. L. Macfarlane, manager of the Captain Cook Coffee Co., regarding the matter of planting these trees on a considerable scale in Kona. On September 3 a few trees were taken to Kona and later, when arrangements were about completed, a larger shipment was sent. These trees were planted out at different elevations ranging from 600 to 2,100 feet. The soil in which they were placed varies from typical rock land, where only pockets of soil are found, to open friable loam. The trees, which were placed under the care of a large number of tenants of the estate and of the Captain Cook Coffee Co., were in some cases planted adjoining each other so as to increase the probabilities of successful cultivation. The tenants themselves displayed great enthusiasm when learning that the trees were to be planted on their lands. All the trees with only two exceptions were placed among coffee plantings at distances of approximately 30 feet, the distance varying slightly with the method that had been followed in placing the coffee trees. The two exceptions referred to were where the Captain Cook Coffee Co. made plantings of trees 25 feet apart on land especially cleared for the purpose, and also where a few trees were planted in the neighborhood of the company's mill.

About 800 seeds of this species were sown at the station greenhouses in the latter part of the year 1918, and some time during the summer of 1919 the seedlings will be in readiness for transplanting.

THE AVOCADO.

Probably the avocado will always be one of the most important fruits grown in Hawaii. No export industry exists for the reason that the fruit is occasionally infested with the Mediterranean fruit fly, with the result that it is subjected to quarantine upon arrival at the mainland ports of the United States. Demonstration, however, has proved refrigeration to be a most efficient method for destroying the eggs, larvæ, and pupæ of the fly; [3] and, in fact, entomologists claim that this method could be used under careful government control to ship the fruit without danger of carrying the pest to uninfested ports. The following conclusions of Back and Pemberton,[4] reached after exhaustive study of the insect under refrigeration, merit very special consideration in this connection:

> The data contained in this paper show that no eggs or larvæ of the Mediterranean fruit fly survived refrigeration at 40° to 45° F. for seven weeks, at 33° to 40° for three weeks, or at 32° to 33° for two weeks. They may lead to the modification of existing quarantines and encourage the refrigeration of fruit subject to fruit-fly attack. It seems reasonable to conclude that sooner or later the certification of properly refrigerated fruit will be practicable. When an association of fruit growers or a people find it financially worth while there is no reason why they can not operate a central refrigeration plant under the supervision of an official whose reputation shall be sufficient to guarantee all fruits sent out from the plant to be absolutely free from danger as carriers of the Mediterranean fruit fly.

After a large quantity of fruits of uniform grade and variety has been produced to exceed local demands, an export trade to the mainland of the United States and Canada can be developed by the adoption of the refrigeration method. Larger productions of the avocado might result, too, in a trade with New Zealand and Australia and, possibly, without the refrigeration treatment of the fruit, since the Mediterranean fruit fly was well established there many years before it was found in Hawaii. The rapidly developing countries of the Orient must not be forgotten in this connection, for as the East becomes more closely united to the West, the avocado will become as popular there as it is now becoming in the United States. A further use for the avocado will be found in manufactured products. The division of chemistry of this station prepared the fruit in several ways and reported favorably upon a test with the bottled product known as Avocado Cocktail.

There is at present, however, a good demand in the local market for all the really choice avocados—a demand which will increase not only as the population grows, but as varieties and methods of packing are standardized. With this standardization the buyer will no longer have to risk getting unsatisfactory fruit, as now too often happens when he buys, but will know exactly what to expect from his

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[3] Hawaii Sta. Press Bul. 47 (1914).

[4] U. S. Dept. Agr., Jour. Agr. Research, 5 (1916), No. 15, p. 665.

orders. Home consumption of the avocado can be easily increased three or four fold by encouraging the growth of those varieties whose fruits mature between October and May; during these months, the local markets are practically bare, except for some immature fruits which are rushed on the markets to obtain the prevailing high prices.

If the avocado were to be used for the home garden only, the high food value of the fruit and its intrinsic worth would justify all the effort that the station has given it and will continue to give it. In view of the larger possibilities of this fruit, it is to be regretted that even greater attention can not be focused upon it. One of the earliest services undertaken by the station was the adaptation of methods of propagation and the actual dissemination of budded trees which made it possible to establish nursery work on a commercial basis. Several of these small nurseries are now in operation where trees of the choicer varieties can be purchased and where one can engage the services of budders to top-work older trees. The station discontinued the practice of distributing budded trees and propagation is now being confined to some new varieties which are being tested in a few small cooperative orchards. With a view to testing their adaptability to heights, a small orchard of trees was planted at an elevation of about 1,000 feet at the station's gardens on Mount Tantalus.

A number of new varieties of the Guatemalan type were received from the Office of Foreign Seed and Plant Introduction of the United States Department of Agriculture. They represent a part of the valuable collection made by Mr. Wilson Popenoe, agricultural explorer, who spent many months in carefully exploring the highlands of that country in search of the most promising types of the Guatemalan avocado. These are of especial interest to Hawaii, because, like the Guatemalan varieties now grown at the station, their fruits will probably mature in the autumn and winter months when the more common West Indian type is out of season; furthermore, they will probably assist in extending the avocado belt to higher elevations in Hawaii, since they were discovered at altitudes between 4,000 and 6,000 feet above sea level. The new varieties recently introduced into Hawaii and their identification numbers are as follows:

Varieties.	Hawaii Station number.	S. P. I. number.	Varieties.	Hawaii Station number.	S. P. I. number.
Lamat	4246	43476	Benik	4255	44626
Kanola	4247	43560	Mayapan	4256	44680
Ishkal	4248	43602	Manik	4257	45560
Kashlan	4249	43934	Cabnal	4258	44782
Pankay	4250	44785	Cantel	4259	44783
Nabal	4251	44439	Tertch	4260	44856
Nimlich	4252	44440	Ishim	4261	45562
Panchoy	4253	44625	Kanan	4262	45563
Tumin	4254	44627			

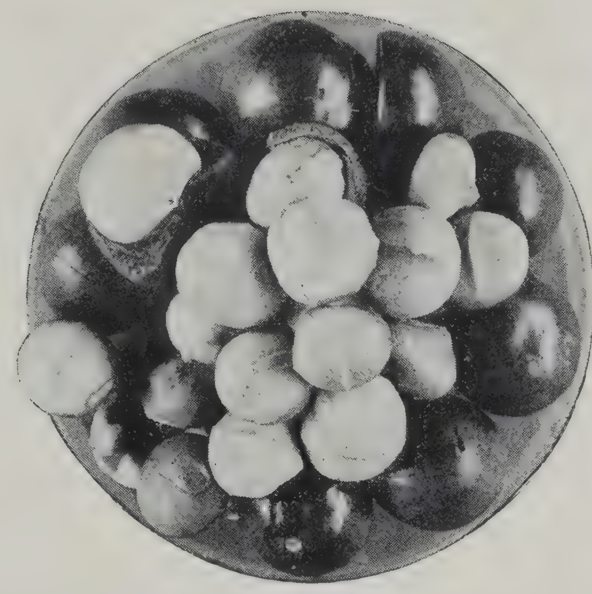
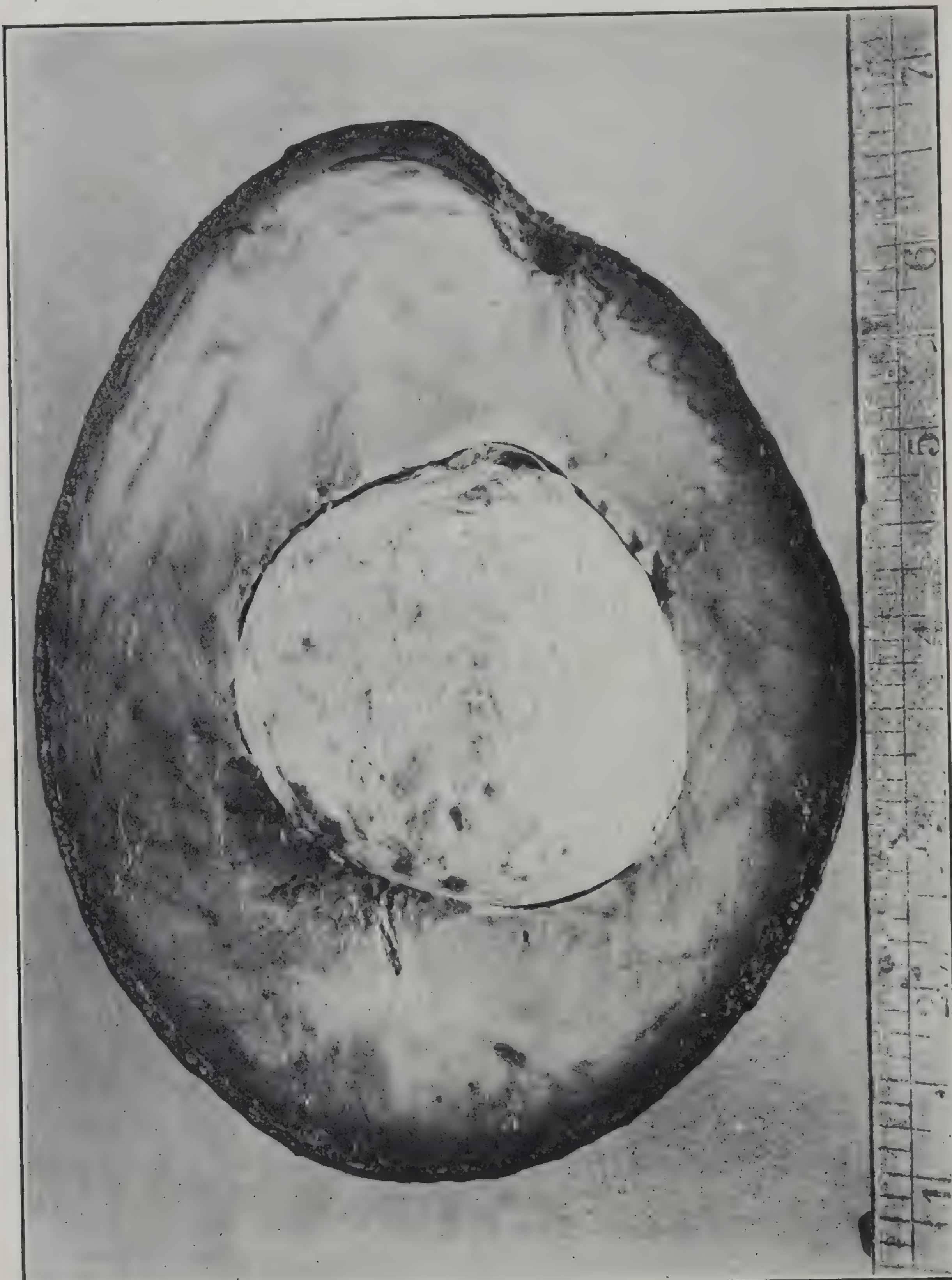


FIG. I.—MACADAMIA NUTS; UNHULLED AND HULLED NUTS AND EXTRACTED KERNELS.

Diameter of plate, 4 inches.

FIG. 2.—THE PIRIE MANGO, A PROMISING VARIETY FOR HAWAII.

Diameter of plate, 10 inches.



THE BEARDSLEY AVOCADO.

Full descriptions of all these are being published in Washington by the Office of Foreign Seed and Plant Introduction, United States Department of Agriculture, and copies will doubtless be available for distribution.

Of each variety, one tree was placed in the small orchard on Mount Tantalus, previously referred to, and others will be planted in different places for trial as they develop.

The Beardsley avocado.—This is a new variety of the Guatemalan type of Hawaiian origin (Pl. II). It is a seedling from the McDonald, one of the two original trees grown from seed first introduced into Hawaii from Guatemala[5] by Admiral Beardsley. Other seeds of the same type are said to have been left at Hilo and probably also on Maui. This new seedling was presented on December 18, 1911, to Mr. L. C. Ables, a careful cultivator who planted it in his home gardens at 1627 Kewalo Street, Honolulu, where the tree now stands. It is known to have produced a crop within four years after planting. The season of maturing the fruit varies, as is the case with all of this type, but it is strictly a fall and winter fruit. The tree is of upright and rather dense habit, a regular and prolific bearer. The fruit is the largest and most perfect of all the Guatemalan varieties that have come under observation at the experiment station. In honor of the benefactor, who introduced the seed of the parent tree, the first of its kind in Hawaii, and who, with much care, maintained their viability this, the best of the progeny that has appeared, has been named the Beardsley.

A description of the fruit in detail by J. H. Cowan, who made the record for the station, is as follows:

Weight 37 ounces, seed $15\frac{1}{2}$ per cent, rind $13\frac{1}{2}$ per cent, and edible portion 71 per cent. Shape round to pyriform. Fruit cavity, flaring, irregular, rounded, $\frac{5}{16}$ inch deep. Rind, a thick, hard shell of purple color on the surface when ripe. Pulp fine-grained with trace of fiber only at the base. Flavor, rich and nutty. Seed tight in seed cavity.

THE MANGO.

The present is an unusually good year for observations on the mango, as nearly all varieties in the station orchard are now in fruit, and other sorts have been brough in by private growers. A very important factor in mango growing is the wide variation shown by these fruits in their susceptibility to the attacks of the Mediterranean fruit fly. Fortunately, the Pirie, which gives promise of becoming the leading variety of all those introduced, and also some others of the choicer kinds are not attacked by the insect if other more attractive fruits are available.

In view of these facts, it would seem desirable to maintain with the choice varieties of mango, some other more attractive fruit, which

[5] Hawaii Sta. Bul. 25 (1911), p. 43.

would act as a trap in which to catch the flies. The susceptible varieties of mango would serve this purpose so far as diverting the insects is concerned; however, if these varieties are allowed to remain in the orchard, all fallen fruits must be picked up and submerged in water in order that the larvæ and pupæ of the fly may be destroyed. Unfortunately, the mango has been found not adapted to the several species of parasites introduced to destroy the Mediterranean fruit fly. According to Pemberton and Willard,[6] parasitism of fruit flies in the mango falls at times as low as 7 per cent of the total number of insects taken from the fruit during an entire month, while the average is uniformly low in the fruit. In coffee, which is a favorite fruit for the fly, there is a high percentage of fruit fly parasitism, running as high at times as 94 per cent. Were a variety of coffee to be found which ripens its fruits during the mango season, this could serve not only to protect the immediate crops, but also to greatly increase the number of parasites and reduce the fly. As above stated, there is in many localities a considerable assortment of fruit more attractive to the fly than the Pirie and some other varieties of mango. This interrelation of fruits, pest, and parasites should be kept in mind as it may frequently be found desirable to plant or graft in some fruit for the protection of the Pirie and of other choice varieties of mango.

The mango seed weevil (*Cryptorhynchus mangiferæ*) has become a very prevalent pest. Fortunately, it remains within the husk of the seed until some time after the fuit has ripened, and does not pollute the flesh of the mango or detract from its external appearance. Nevertheless, its presence within the seed often affects the appearance and even the flavor of a portion of the flesh surrounding the seed. In the case of the Pirie and some other good varieties, this injury is very slight unless the fruit is allowed to become overripe. The greatest injury is done to the seed, which, if allowed to remain within the husk, is usually destroyed. It is estimated that about 90 per cent of all the seeds opened at the experiment station this season were weevil infested and, therefore, unfit for propagation.

Various means are being tried to save the seeds from complete destruction. One of these consists in cutting open the husk as soon as it can be cleaned and slightly dried. When wet the husk is extremely difficult to cut, but when dried for about one day, it can be cut at the lower end at a point corresponding to the stigmatic point of the fruit; this cut may be extended up the ventral edge of the seed so as to permit the entrance of the thumb of each hand, with which the husk may be pried open and the seed removed. If the seed is found to be weevil infested, but not yet fully destroyed, the insects can be killed, the seed cleaned, and then planted. If the embryos of the seeds, many of which are polyembryonic, have been

[6] Jour. Agr. Research [U. S.], 12 (1918), No. 2, p. 106; 14 (1918), No. 13, p. 607.

destroyed, the seed will be useless, but should one or more of these remain uninjured, the seed can be expected to grow. Seeds planted without the husk require on an average 18 days to germinate, while those planted with the husk require on an average about 40 days to germinate.[7] It should be remembered that the only way to distinguish unsound seed is to open it. If such a seed were planted without having been opened, the long period required for germination would suffice for its utter destruction by the weevil within.

When a large percentage of the seeds has been found to be injured beyond the possibility of recovery, the removal of the seeds from the husks becomes a somewhat expensive though very necessary means of securing seedling plants. A less expensive, but less effective, method tried for the destruction of the insect consisted in making one rapid cut at the lower end of the seed as described above, after which the seeds were placed in a sack and submerged in water for one hour. Seeds so cut were also fumigated and, the weevil, which manifests a high degree of resistance, killed. The seed when cut open is moist within, but determination has not been made as to whether it can endure as much fumigation as the weevil will, or whether the frass or refuse created by the weevil will contribute to the decay of the injured seed.

MANGO VARIETIES.

This season has offered excellent opportunity not only for noting the local adaptability and characteristics of the mango varieties, but for establishing the synonymy of certain names. Lack of space prevents a detailed pomological description of each variety, but a few notes will serve to record the outstanding features of a number of them and to indicate those which seem best adapted to local cultivation or which are of most interest from the standpoint of breeding.

Pirie (Pl. I, fig. 2).—This variety is considered the best, at least for lowland conditions, of all the mangoes that have been introduced into Hawaii. It is of medium size, inclining to the rounded form, with a distinct beak at the stigmatic point. The surface is smooth and, when ripe, is a pale yellow beautifully marked with crimson where exposed to the sun. It is practically fiber-free, has a delightful aroma, and is as soft and juicy as a ripe peach. The seed is easily removed, so that the fruit can be served in halves and be eaten with a spoon without the slightest inconvenience. In order to remove the seed, it is only necessary to make a cut circling the fruit, about midway its length, and extending as deep as the surface of the seed. Then, by a slight twisting motion, one half of the fruit can be separated from the seed, leaving a smooth, unbroken surface within. By cut-

[7] Hawaii Sta. Bul. 12 (1906), p. 10.

ting very slightly around the seed, it may easily be removed from the remaining half of the mango. The flavor is so unusually delicious as to put this mango in a class of its own in Hawaii. The Pirie is less subject than other varieties to the black spots caused by the fungus *Colletotrichum glœosporioides*, and, while not immune to the fruit fly attacks, it either possesses a high degree of resistance, or is not a preferred variety for the fly. No injured fruits were found in this variety in the station orchards this season, though crops of several of the other varieties were rendered almost worthless.

Kavasji-Patel (*Cowasjee-Patel*).—This is one of the largest of the Indian mangoes introduced into Hawaii, being excelled in average weight only by the Sundersha. It inclines to the rounded form, is somewhat depressed on the ventral surface, and in color is pale green, which turns to yellow as the fruit ripens. The texture is excellent, but the flavor is somewhat inferior to that of the Pirie. The tree makes vigorous growth, but is a shy bearer.

Jamshedi.—This is a mango of large size approaching more nearly the spherical shape than most mangoes. It is of green color even when ripe, and has a good flavor and texture. The chief weakness of the variety seems to be its lack of attractiveness in color. The tree is a free bearer.

Mullgoa.—The Mullgoa is a large variety closely resembling Jamshedi, but distinguished from the latter variety by the large pale green spots which appear on the fruit.

Mulgoba.—This variety, which has proved so popular in Florida, has not attained prominence in Hawaii. The fruit is of medium size, being about the same in this respect as the Pirie. It is of good flavor and texture and is golden yellow when ripe, often splashed on the shoulder with red. The name has been considered by some as a probable synonym of Mullgoa, but it is a wholly different fruit, much more yellow and elongated.

Strawberry.—The tree, received under this name from India through the Office of Foreign Seed and Plant Introduction of the United States Department of Agriculture (S. P. I. No. 10643) seems to be identical with Pirie.

Peter's No. 1.—The variety received under this name fromTrinidad, through the Office of Foreign Seed and Plant Introduction (S. P. I. No. 3706) also appears to be identical with Pirie. Doubtless the name is a more recent one than that of Pirie, which is an old established East Indian name.

Alphonse.—This variety has attained great fame in India, but, because of its lack of flavor, it has failed to become popular in Hawaii. It is of medium size and quite distinct in shape, being flattened on the ventral surface and without any prominent stigmatic point. The

Alphonse is indeed a handsome mango, being golden yellow in color and beautifully marked with crimson on the shoulder.

Hafu.—The Hafu is apparently a synonym of Alphonse.

Douglas Bennett's Alphonse.—Up to the present no consistent points of difference have been distinguished at the station between this variety and those received under the name "Hafu" and "Alphonse." However, a closer study of a large number of trees may reveal points of difference.

Ameeri.—The variety known as Ameeri is probably the most magnificently colored of all the mangoes introduced into Hawaii. It is elongated in shape and rather symmetrical, the exposed side being overlaid with a purplish hue, which changes to a gorgeous crimson on ripening, while its unexposed surface turns yellow. This mango is of good texture and fairly good flavor. The tree is vigorous and a good bearer. Because of its remarkable coloring, the Ameeri is well worth growing as an ornamental and should be of special interest to any plant breeder who desires to combine these color characters with the flavor or other desired characters of Pirie, which, though beautifully marked, has coloring less striking.

Brindabani.—The most prolific of all the mangoes that have been introduced is the Brindabani. The trees have been regular and abundant bearers, apparently devoting all their energies to the production of fruit. After they attain the bearing age they do not make rapid vegetative growth, though in healthy condition. The fruit, which is rather small and quite round, is green, the exposed surface being overlaid with dull brown or reddish tints. The flavor and texture can hardly be rated higher than fair, but it has the advantage of maturing very late, after most varieties have passed their season, and it is probably as nearly immune to the fruit-fly as any mango in Hawaii.

Totafari.—The Totafari is a handsome bright yellow mango, somewhat large, elongated, and rather symmetrical, with a prominent stigmatic point. It is of good texture, decidedly acid flavor, a reasonably good bearer, but quite susceptible to fruit-fly attacks.

Sundersha.—This is perhaps the largest mango in Hawaii. Its shape, which makes it unfavorable as a commercial mango, is very distinctly that of the letter S found also in the No. 9 mango quite familiarly known in these islands. The Sundersha is well colored and altogether a handsome mango, though not equal in flavor to some of the other varieties.

Divine.—This, the most inappropriately named of all mangoes, if judged by its performance in Hawaii, is of small size, extremely subject to the black spot disease referred to elsewhere, rather green in color, and well marked with red on the shoulder where not injured

by the disease. The flesh, which possesses only a fair flavor, is highly colored, of fair texture, and surrounds a rather large seed.

Cambodiana.—Cambodiana is of an entirely different type from any of the true Indian mangoes. It was received by the Office of Foreign Seed and Plant Introduction from Saigon, Cochin China, and is regarded by some botanists as a distinct species, to which has been given the name *Mangifera cambodiana.* Evidently to this type belong the numerous seedling varieties which have long been known in Hawaii under the name Chutney mangoes, sometimes spoken of as Chinese mangoes. All of these possess a distinct aroma, the foliage having a peculiar odor and a characteristic color and shape which distinguishes this type from the Indian varieties. The fruit of the Cambodiana is of medium size, beautiful golden yellow in color, and possesses a delightful subacid flavor in the highly colored flesh, which is of good texture and fiber free.

Wootten.—The Wootten is a variety of local origin belonging evidently to the Cambodiana type or to a cross between this and some variety of the Indian type. It is of medium to large size, of golden yellow color, slightly touched with red on the exposed shoulder, of good texture and rich flavor. One of the most important features of the Wootten, which permits its being marketed in an attractive condition, is the fact that the fruit remains hard while developing a remarkably good coloring. Some otherwise excellent mangoes fail to develop a good color until they are quite ripe.

Smith.—The Smith is another variety of local seedling origin and of the Cambodiana type. It closely resembles the Wootten, but it is earlier, of smaller size, and a little more highly colored on the exposed shoulder.

Number 9.—This is a variety, or perhaps more properly a type, introduced under this name many years ago by the government of the Hawaiian Islands. Many seedlings of it have appeared, most of them rather closely resembling the original type introduced. Practically all of these incline to the letter S shape, are very juicy, fibrous, and not highly flavored. The trees are abundant bearers, make vigorous growth, and produce handsome fruit rather free from the black spot disease.

Victoria.—The Victoria is a very beautifully colored variety of the No. 9 type grown by Mr. T. G. Thrum, Thurston Avenue, Honolulu.

Hawaiian Sweet.—This is more probably a type than a variety. It was the first mango, and among the early acquisitions of foreign fruits, introduced into the Hawaiian Islands, and was probably brought here by the late Don Marin. Few of its many seedling varieties, all closely resembling each other in shape and flavor, have been considered worthy of propagation by grafting or budding.

Oahu.—Probably the only seedling of the Hawaiian Sweet mango that has proved sufficiently distinct and valuable to cause it to be given a name and to be propagated by grafting is the Oahu. This remarkably handsome mango is large, possesses a mild and sweet flavor with abundant juice and has better texture than the average of its class. Many of the fruits show a tendency to be seedless, their husk containing no seed. This character, however, is not constant.

THE TOP-GRAFTING OF MANGO TREES.

Earlier reports and bulletins of the station described methods developed for the top-working of mango trees. Hawaii, however, is not a country of orchardists, and these methods were not applied as widely as they might have been had there been available someone who could be employed to do such work. The station, therefore, undertook, about two years ago, to forward this movement by detailing to the work on part time a man who had long been in training here. As the work developed, there appeared to be a large opening for an expert propagator in this and similar lines. The station, desiring to relinquish its operations as soon as assured that the work would be continued independently, and that owners of trees could get an experienced propagator to graft them, withdrew, leaving the work to be carried on as a private business by two men. In order to disseminate choice kinds of fruit the station supplies scions of the best varieties to these men or to any others who desire them. One of the most progressive of the large sugar plantations planted several hundred seedling mangoes along its avenue, and is having them grafted with choice East Indian varieties.

The very excellent crop of the Pirie variety this season made it possible to bring this fruit to the attention of the people by exhibitions which were held in prominent places in the city; and, at a luncheon given by the Honolulu Ad Club, its excellent qualities were demonstrated. This club has appointed a committee to aid in forwarding the movement for better mangoes in Hawaii, by means of substituting the Pirie and other choice varieties for the many inferior seedlings. As soon as the merits of these more recently introduced varieties become widely recognized, there will be a general movement to produce the best; the Territory will then be supplied, as it ought to be, with mangoes of real merit, and, should the quarantine regulations undergo changes suggested by Back and Pemberton in their above-mentioned discussion of the avocado, the exporting of mangoes may very easily become an important industry.

The station this season is conducting experiments in canning and drying the Pirie, and should either of these methods prove successful in producing a preserve which approaches the excellence of the

fresh fruit, an industry of very large possibilities would undoubtedly be developed.

THE SOLO PAPAYA.

This variety of papaya (Pl. III, fig. 1) which has been under cultivation through four generations, has transmitted its characteristic flavor and texture, and to a reasonable degree its shape, in all of the plants of its kind that have come under observation. To this variety has been given the name "Solo." It is quite small, in some instances the fruits permitting of only one serving; in others, the fruit is large enough for two servings. Most plants of the variety are hermaphrodite or bisexual, but a staminate tree is found occasionally. Although the fruits are small, they are crowded into the axil of nearly every leaf and are so numerous that the yield is reasonably heavy, yet not equalling in weight that of some of the large kinds. The fruit is pyriform, somewhat irregular, colors well and uniformly before softening, and is free from the diseased spots which attack the surface and penetrate the pulp of many of the large forms, The flesh is of medium thickness, of bright yellow color, smooth. tender almost to melting, and of delicious flavor even near the stem end where many papayas lack flavor. The seeds, which are abundant, permit of ready and rapid means of propagation, and, because of the loose placenta or inner lining of the fruit to which the seeds are attached, they are very easily removed when preparing the fruit for serving. From the standpoint of the home gardener, the Solo is considered one of the best of the papayas that have been grown at the experiment station, for, although small, its qualities of texture and flavor give it first rank. The Solo can be used as an individual fruit.

This variety is being quite widely disseminated throughout the Territory by the distribution of seeds and seedling plants. Several other kinds of papayas, under selection for several years, were also sent out in rather large quantities. The purpose of this distribution was to establish the best varieties in as many places in Hawaii as feasible, and also in other parts of the Tropics. Nearly every mail brings requests for seeds of the Hawaii Station selections. In general, it is possible to assign to each applicant only a limited quantity for trial and further propagation, but on one or two occasions where a hurricane had destroyed much of the vegetation, as was the case in the island of Guam, several pounds of seed were sent. In one or two cases, cooperative plantings were made where it was possible to keep them under close observation.

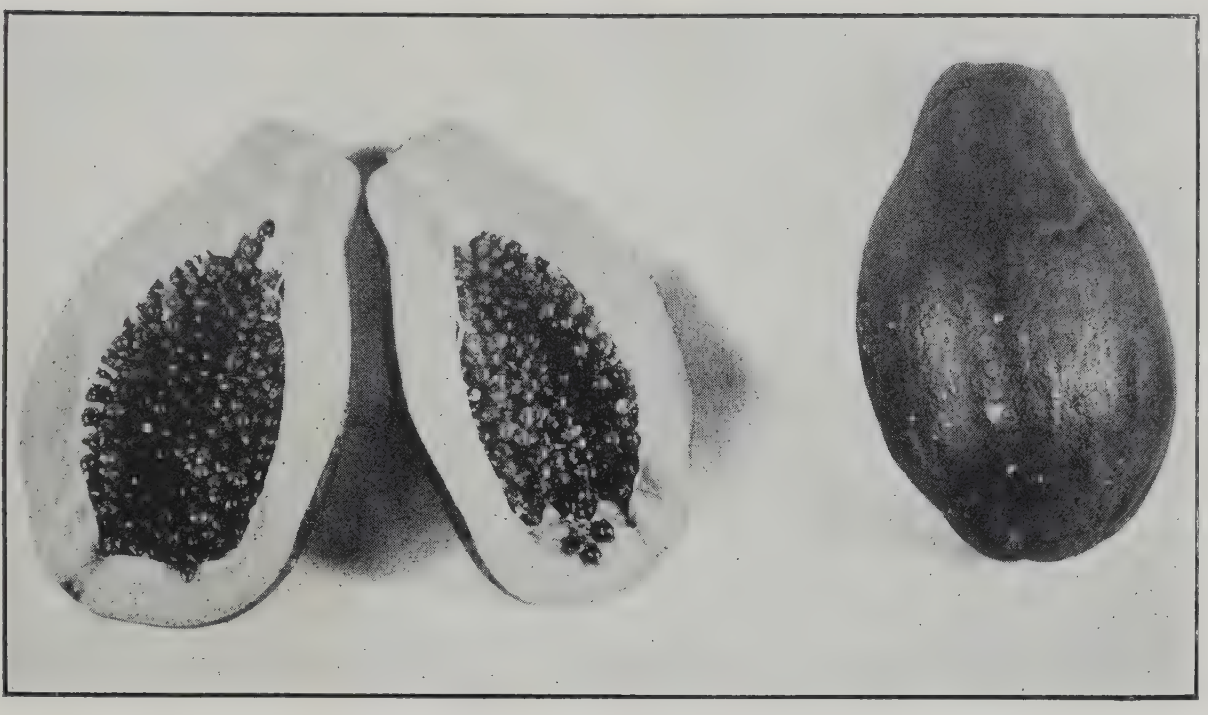


FIG. 1.—THE SOLO PAPAYA. LENGTH OF FRUIT 6 INCHES.

FIG. 2.—TRUNK OF LITCHI TREE BROKEN OFF JUST BENEATH SURFACE OF SOIL, SHOWING (*a*) DEAD STUB OF LAYERED BRANCH.

FIG. 1.—LONGAN TREE SHOWING INHERENT WEAKNESS IN STRUCTURE DUE TO MANNER OF ATTACHMENT OF BRANCHES.

FIG. 2.—BRANCH BROKEN FROM TREE FIGURED ABOVE, SHOWING MEAGER ATTACHMENT.

THE LITCHI.

It has not been possible to extend the investigations of the litchi as rapidly as was desired. The propagation of the varieties in the station collection is being continued. In the latter part of May, 1917, G. Weidman Groff, professor of agriculture in the Canton Christian College, Canton, China, arrived at Honolulu en route to Washington, D. C., bringing with him certain varieties of litchi plants intended for the Office of Foreign Seed and Plant Introduction of the United States Department of Agriculture. These varieties did not endure the journey well, and it was feared that a further trip of 5,000 miles would result in their total loss. The plants were, therefore, left in the care of this station where it was possible to restore to a growing condition the following varieties: Waai Chi, Kwei Mei, San Hing Heung Lai, Saam Uet Hung, Haak Ip, and T'in Naam. It was possible to cooperate with the Office of Foreign Seed and Plant Introduction also in aiding the further trial of the litchi in Florida by shipping to Washington in June, 1918, 25 pounds of fruit to be used for further propagating this species.

It is well known that the customary method of propagating the best varieties of litchi is that known as Chinese, or air-layering. This consists essentially in the removal of a ring of bark from a branch, and surrounding the wound with soil or moss which is kept constantly moist until root formation takes place from the upper or outer side of the wound. It is, however, questionable whether such a root system is ever as satisfactory as that produced from the growth of a seed. Plate III, figure 2, shows the stump of a litchi tree broken off just beneath the soil by the storm which occurred early in December, 1918. In the center of the wound may be seen, at the point *a*, the remains of the old branch which was layered to produce the new tree. This small piece of dead wood was simply the remains of the old branch from which the bark had been removed, and was of no service to the new tree after it extended downward beyond the root system. It will be seen that the root system was apparently very meager, although this tree had reached a height of 10 or 15 feet. Further observation disclosed the fact that the grain of wood at the point of junction between the roots and the stem was hardly favorable to strength of structure. It is often noticed when taking young litchi layers from a parent tree that only one or two good roots have formed. It is problematical whether further roots grow except those which serve as an extension and amplification for the roots present when the layer is taken from the tree. Whether or not an exhaustive study has been made of the root systems of air-layered litchi trees is unknown to the writer. It was pointed out in

an earlier publication [8] that the system of air-layering is likely to be superseded by the budding or grafting of the litchi on seedling stocks of its own, or of some closely allied species. Present observations on the root systems of an air-layered tree, suggest a further possible reason for developing other methods of propagation than that commonly practiced in the land of the litchi. In Bulletin 44, above referred to, reference was made to the temporary success of grafting the litchi on the longan. For more than a year these grafts remained in a flourishing condition, but later a peculiar condition developed which resulted in the failure of all the trees. This failure was attributed to incapability on the part of the litchi growth to sustain the longan stock upon which it was placed. Shoots were sent out by the longan, but these were persistently removed to encourage the growth of the litchi. In some instances large swellings were thrown out by the litchi branches, some distance above the point of union, suggesting the possible backing up or concentration of material at these points. Prof. Wilbur MacNeil, of the Oahu College in Honolulu, grafted scions of the litchi from this station into one or two branches in the top of a longan tree in his garden. This work was done at the time when the station trees gave promise of success. These branches continue to grow in the top of the tree surrounded by longan branches, a fact which bears out the theory that incompatibility between the stock and the scion is due to inability of the scion to nourish the stock.

The structure of the longan tree.—Attention is herein directed to certain observations on the structure of the longan tree. Although this species does not at present give great promise as a stock for the litchi, it is well worthy of cultivation for its own fruits. Plate IV, figures 1 and 2, shows the manner of attachment of the branches of the longan, and also a large wound caused by the breaking off of a branch under the stress of wind. A careful study of the attachment of the two remaining branches shown, and of the wound, will prove inherent weakness in the manner of attachment of the branches. It will also be seen from the wounded surface of the removed branch, as well as from the wound on the remaining branch, that there was practically no attachment above the point where the grain in the branch was parallel with the grain in the remaining limb. These observations point to the importance, when pruning, of selecting branches of the best possible attachment for the formation of the main framework of the tree and of the early elimination of branches that are very poorly attached.

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[8] Hawaii Sta. Bul. 44 (1917), pp. 10, 11.

COFFEE.

In September, 1918, the horticulturist made a trip to the island of Hawaii for the purpose of investigating certain phases of the coffee industry of that island, especially regarding its status, its needs, both from an agricultural and from an economic point of view, and the availability of some of the by-products of coffee culture as possible sources of caffein.

As an introduction to notes relating to coffee, there is herewith submitted a brief review of the system now commonly used in coffee growing in Hawaii, and the process of preparing it for market, which perhaps may make more clear certain statements relating to by-products and also to the present conditions of the industry. Coffee is grown in Hawaii chiefly on the tenant-farm system. In the Hamakua district there is one large plantation which is cultivated by the owners with employed labor. This plan may be carried out to a limited degree by some planters in Kona, but for the most part the lands, in lots varying from 5 to 25 acres, are leased to small growers. In many instances, these lands are leased from the owners by coffee companies, these in turn subleasing them to others. A large part of the crop, while still in the cherry, is sold to the mills. A considerable portion also is pulped and dried by individual owners on small drying floors and later sold in the form of parchment coffee. The pulping is sometimes done by a small machine in a given locality for a small charge, when the coffee is returned to the owner for drying. The small growers do not attempt to remove the parchment, because the machinery required for this process is somewhat expensive, and some large growers prefer to hire this service rather than install the machinery for the work.

In Hawaii the process of preparing coffee for market is the one commonly employed for washed coffee. After it is picked, the coffee cherry is taken to the pulpers as promptly as possible, though it does sometimes remain in the bags for two days or more. It is then passed through the pulping machinery which separates the seed from pulp. The small machines consist of a roller having a rough surface. To secure a rough surface, the roller is sometimes covered with a sheet of brass through which holes have been made from the under surface. The heavier machine used in the mills consists of series of three or four rollers, the first of which crush and separate the larger fruits, and the later ones the smaller. The pulp is carried away by hand or by automatic carriers to a convenient place where it is allowed to ferment. After fermentation takes place, the pulp is used for fertilizer, and in the larger mills it is used in part for fuel. The coffee seed as it is separated from the pulp is covered with a sweet gelatinous substance which must be removed before the coffee can

be properly washed and dried. To facilitate its removal, the wet coffee passes to fermentation tanks where it is allowed to remain for 24 hours or more, after which it can be washed. In the larger mills there are revolving washing machines which churn the coffee with water and remove the gelatinous cover. The cleansed seed is then taken by automatic carriers, or, in the case of a small grower, by hand, to the drying floors where it is spread out for the first drying. Every precaution is taken to prevent rain from falling upon the beans. From time to time, as necessary, the seed is turned and stirred so as to prevent musting, and to hasten drying. At the mills, after the free water has been eliminated, by the first drying process, the coffee is taken by automatic carriers into the mill for more complete artificial drying, various devices being used for this purpose. When sufficiently dried, either by natural or artificial methods, it is ready for sale as parchment coffee. The outer husk or parchment-like cover is then removed, and the thin, soft covering, known as the silver skin, or waste material is separated from the cleansed coffee bean. The best machinery also grades the beans according to size, after which damaged beans are removed by hand from the best grains. On a large table, which is divided into compartments or bins, the beans are usually spread out sufficiently to make it possible to quickly find and remove the undesirable ones. In one mill at least, where machinery used for this process is under the control of the operator, a movable-belt table passes toward him, carrying a small quantity of coffee beans from which damaged specimens are picked out by hand. It is chiefly in this form that most Hawaiian coffee is marketed for export trade, though roasting, grinding, and packing are used to a limited degree.

Present status of the coffee industry.—The coffee industry in Hawaii, in addition to struggling for many years against competition with imported coffees grown on cheap land by low-priced labor, was, as a direct outcome of the war, completely cut off from many of the large markets of the world; prices dropped so low that coffee growers received less than in prewar times, and the cost of production was necessarily increased by the rise in the price of labor. Still more serious was the rise in the price of commodities which coffee growers need for their maintenance. Many of the growers are of oriental descent, and rice is their staple food. As one of the growers stated the condition: "Before the war three bags of coffee cherry would buy one bag of Japanese rice. Now it requires eight bags of cherry to buy one bag of rice." Rice advanced from \$5 to \$6 per bag to about \$13, and coffee cherry fell from over \$2 per bag to \$1.65. While the American farmer on the mainland paid high prices for certain commodities, he received in return large prices for his agricultural pro-

ducts. The tide for the Hawaii coffee growers on the other hand was against him both in the price of production and distribution.

At the time of the present writing, June, 1919, the price of coffee has advanced to a price which breaks all recent records. This is, no doubt, due in great part to conditions brought about by cessation of war and the reopening of European markets, and perhaps also to frosts which are reported to have occurred in some of the coffee producing areas of Brazil. This rise in price probably came too late in the season to prove of immediate benefit to the producers, the sale of their crop being generally arranged in advance of the harvest season, or very soon thereafter because of shortage of funds. Should these high prices prevail through another harvesting period, coffee growers may expect to profit by the advance. Since, however, these prices can not be expected when normal conditions are restored, everything possible in the meantime should be done to assist this struggling industry of Hawaii.

Agricultural needs of the coffee industry.—Some years ago the green scale, *Coccus viridis*, menaced the industry; this pest is now however controlled by natural enemies. From an agricultural point of view there is no reason why the coffee business might not be greatly extended and it doubtless would expand rapidly were economic conditions to change in its favor. There is need, however, for experimental work along many lines. In Kona, one of the leading districts, no shade has been used on most of the plantings. Many of the trees have suffered no doubt for want of shade, but only after careful trial can it be determined where and under what conditions shade trees are needed, and what trees are best adapted to this purpose. The experiment station used a few trees of the *Inga laurina*, which were planted for trial by the Captain Cook Coffee Co., while the silver oak (*Grevillea robusta*), kukui (*Aleurites moluccana*), and others were tried to some extent by others. Very careful investigation, however, should be given the subject of shading so that definite data will be available.

Pruning of coffee trees in Kona, Hawaii.—In Kona no very definite method of pruning coffee trees is practiced by most growers. Pruning experiments are needed to determine their relation to shade, to varying distances required for planting, to ascertain individual differences in trees, and also to discover their relation to prolonging the life and increasing the productivity of the trees. The trees were planted at distances varying from 4 or 5 to 10 feet apart; the tendency appears to have been that of too close planting. Another matter needing immediate attention is that relating to proper distances in planting. Many of the older trees, where planted very close, have grown to great height for light and air and practically their only

bearing surface is on top. Only a small bearing surface has been the result, therefore, despite the fact that a large number of trees were planted to the acre. Some experiments might be well worth while in order to determine whether it would be practicable to restore these old trees to health and productivity by some renewal system. Fertilizer experiments are also needed in order to determine their most effective and economical use.

Another promising field for experiment would be to select trees of unusual vigor and productivity and propagate them by asexual methods so as to develop greater uniformity. These methods of propagation might also prove of value in top-working old plantings to a superior strain. At present there are only two recognized commercially grown varieties in Hawaii, one known as the Hawaiian coffee, the progeny probably of a very early introduction, and the other the Guatemalan, which was introduced 20 or 30 years ago during a time when coffee growing was prospering.

Budding and grafting experiments.—Certain simple trials in budding and grafting, along the lines just indicated, were undertaken by the writer during a brief stay in Kona. Mr. L. Macfarlane, manager of the Captain Cook Coffee Co., called attention to a few trees of the Maragogipe variety of coffee grown for trial from seeds introduced by him some years ago. This variety of coffee was discovered in Brazil about 1870. It produces a large berry and large bean, commands fancy prices and is well worth very careful trial in Hawaii. Mr. Macfarlane secured the variety in Mexico, where it is grown to some extent. Buds from this variety were inserted on the main stem of some 2-year-old trees, and also on a few suckers in the upright-growing branches of older trees. Scions were also taken from this variety and were inserted as cleft grafts and also as bark grafts on the main stem of 2-year-old trees and also on the large upright growths of older trees. Coffee trees make two distinct forms of growth, the upright and the lateral. It has been found that coffee buds taken from the lateral growths continue to produce lateral growth in the new trees on which they are placed, and it is only by the use of the dormant buds subtending laterals on upright growths that it is possible to secure a normal upright budded or grafted tree. A letter from Mr. Macfarlane concerning the outcome of this work, which was performed shortly before leaving Kona, indicates that the budding was quite successful on the younger trees but on the older stocks grafting succeeded better than budding. However, the work was on too small a scale to justify any general conclusions as to the best methods of propagation, and should be regarded as preliminary to further experiments which may be carried on.

Coffee by-products.—In a letter from the Chief of Insular Stations, States Relations Service, United States Department of Agriculture,

it was requested that the practicability of recovering the caffein in coffee pulp, prunings, etc., be investigated in Hawaii. The following extract of a letter from Dr. Frederick B. Power, pharmaceutical research chemist in charge of Phytochemical Laboratory of the Bureau of Chemistry, United States Department of Agriculture, presents the problem:

> This laboratory has for some time been interested in the question of the utilization of sources of caffein other than those heretofore employed. A preliminary examination of coffee leaves and coffee pulp obtained from Porto Rico have shown that they both contain appreciable amounts of caffein. It would be of interest to us to know to what extent such material would be available and at what period of the year the leaves and pulp could be obtained.

An investigation was made in Kona and in east Hawaii to determine the amount of such materials as might be used in this way, and also their present uses and the possibility of their availability for the proposed purposes. These two districts comprise nearly all the coffee-growing parts of the Territory, the remaining scattered portions producing probably less than 5 per cent of the whole crop.

Kona and east Hawaii produce approximately 50,000 bags of clean coffee per year, more than 80 per cent coming from Kona. About 6 bags of coffee cherry, or 600 pounds, are required to yield one bag, or 100 pounds, of cleaned and dried coffee. This means that of the 30,000,000 pounds of coffee cherry produced, 5,000,000 pounds are marketable coffee. It requires 120 pounds of coffee in the parchment to make 100 pounds of clean coffee ready for market, the loss of 20 pounds representing the horn skin, or parchment, the silver skin, and an occasional bad bean. For every 500 pounds of marketable clean coffee there have been eliminated 100 pounds of this waste material. There are, therefore, approximately 1,000,000 pounds of this dried material produced annually.

The proportion of weight of pulp to the entire weight of cherry has not yet been carefully worked out at the coffee mills, since there was no special reason for determining it, and further because water is usually added in the pulping process. From two 10-pound samples of coffee cherry gathered from the station plantings on Mount Tantalus it was estimated that the pulp constituted approximately 47 per cent, including the water lost in the pulping process. The wet beans represented 53 per cent of the whole and the pulp contained 80 per cent water. The proportions of pulp and of moisture in the pulp would vary with different climatic conditions, and with the different varieties of coffee, but these figures are only approximate.

From the 30,000,000 pounds of cherry there would be 14,100,000 pounds of pulp. Of this, 20 per cent, or 2,820,000 pounds, represents the weight of dry matter.

To summarize, it may be said that at present the by-products from the coffee cherry in Hawaii are about as follows:

	Pounds.
Parchment and silver skin	1,000,000
Pulp:	
Containing 80 per cent moisture	14,100,000
Moisture free	2,820,000

This material, if desired, could be secured chiefly in the late summer and the autumn when the crop is being gathered and milled. It is difficult to estimate the weight of prunings that might be available for the purpose of caffein extraction. Many of the plantations or coffee farms do very little pruning; a few others prune quite systematically. At the present time there may be 2,000,000 pounds of prunings, but this amount would increase manyfold were the material to be sold at a price high enough to pay for the cost of the labor. While the advantages of judicious pruning are recognized in Hawaii, the prevailing precarious conditions of the coffee business has caused growers to hesitate to undertake the expense of pruning, particularly now that labor is so high and difficult to secure. Those widely scattered prunings now available are practically waste and they can be secured for little more than than the cost of gathering.

The dry products, silver skin and the parchment, generally used for fuel, are considered waste products at some of the mills. These could probably be available for the extraction of caffein if this operation proved profitable. The silver skin and parchment are centered at some of the half dozen mills in Hawaii.

The pulp is used in part as fuel, but the most of it is returned to the soil to act as fertilizer. Its value as fertilizer probably would be a criterion of the price required to secure the material for some other use. In November, 1911, an analysis of coffee pulp as a fertilizer was made by Mr. S. S. Peck, at that time chemist of the experiment station of the Hawaiian Sugar Planters' Association. Through the courtesy of Mr. P. S. Burgess, chemist of that station, a copy of the analysis made is submitted herewith.

Analysis of coffee pulp.

	Moisture free.	Original material.		Moisture free.	Original material.
	Per cent.	*Per cent.*		*Per cent.*	*Per cent.*
Water		62.00	Potash	3.91	1.49
Phosphoric acid	0.54	.21	Total ash	9.97	3.79
Nitrogen	2.18	.83			

In addition to the actual content of its fertilizing constituents, coffee pulp is thought to be quite valuable as an amendment to the soil. In a tropical country where humus is rapidly depleted from a soil that is kept constantly under cultivation it is important that the

value of the pulp as a substitute be considered. Coffee pulp is much more widely scattered than parchment and silver skin because many small growers do their own pulping with hand pulpers or by those operated by gasoline engines. A considerable portion of the pulping work is, however, centered at two or three mills.

VANILLA.

Some attention was given to the present status of vanilla cultivation in Kona, where two or three attempts were made to establish an industry. Capt. R. V. Woods is successfully producing vanilla beans and an extract of fine quality. In another part of Kona a large number of healthy vines were found climbing onto trees in a tropical jungle where an extensive vanilla plantation had been abandoned. Were a number of cuttings from these plants disseminated for trial among coffee growers and others they undoubtedly would make thrifty growth in some parts of the Territory even better adapted to the needs of vanilla than Kona. The plant requires humidity and heat, and Kona is inclined to be cool in most of the humid parts. The vicinity of Hilo or the Puna districts of the island of Maui probably would prove favorable spots for future tests.

PINEAPPLES.

The propagation and planting of seedling pineapples was furthered and several thousand of the young seedlings were placed in the commercial pineapple fields of different localities. A few of the first plantings made under these conditions are now beginning to fruit. Interest in the growing of pineapple seedlings developed to a remarkable degree and the work was entered into by the Hawaiian Pineapple Packers' Association on a scale exceeding the financial means of this station. It is gratifying to see this promising work being developed in such a vigorous manner.

THE ALGAROBA TREE AND RELATED SPECIES.

A number of species of Prosopis, introduced as seeds from several parts of the American tropics, were planted on the station grounds, where they are under close observation. Some of these are about to begin to fruit, and the character of their fruit and foliage will soon be apparent. Several thousand seedlings were grown from the seeds of selected trees in cooperation with plantings made by those who are interested in the algaroba-bean industry as a source of ground feed for stock. Some of these were distributed on the other islands of the group, and near Honolulu, where a large planting was made, plans for future observations are under way.

NEW OR RARE PLANTS.

Through the kindness of Mr. John Scott, of Hilo, the station was presented with a number of fruits from the only bearing tree in Hawaii of the ivory nut palm (*Cœlococcus carolinensis*). These nuts, which are illustrated in Plate V, figure 1, are the source of a material which is known as vegetable ivory, and which is frequently used in the manufacture of buttons and similar products. Although this tree will probably be of little, if any, economic importance to Hawaii, it is of considerable interest as an ornamental and as a specimen of an economic plant. Some of these seeds are sprouting in the station greenhouse despite the fact they are said to be difficult of germination.

The Mandarin vine (*Holmskioldia sanguinea*), which was collected by the horticulturist in Porto Rico in 1914, is proving to be a valuable acquisition to the ornamental plants of Hawaii. While it is naturally a climber, it can be grown without support. From a distance its handsome, brick-red colored bracts suggest the brick red variety of the bougainvillæa.

Among the other new or recently introduced plants are a superior variety of Chinese jujube (*Zizyphus jujuba*); Paraguay tea (*Ilex paraguayensis*); a timber bamboo (*Phyllostachys bambusoides*); several varieties of pineapple; several species of Cinchona, which furnish the cinchona or Peruvian bark, the source of quinine; several species of citrus relatives; snake gourd or Guada bean (*Trichosanthes anguina*); and several varieties of mulberry.

HORTICULTURAL EXTENSION WORK.

A large part of the time of the horticulturist is at present required in extension-work activities. During the past two years some of these were carried on in connection with the annual Territorial fairs, one of the main objects of which was to foster and further interest in local production so as to increase the food supply of the island. The exhibit of the horticultural division, which occupied one side of the station booth, showed some of the more recently introduced plants, the methods pursued in propagating pineapples from seed, a number of tropical fruits which were preserved in exhibition jars, the method pursued in growing strawberries in a barrel on small city lots, Macadamia nuts shelled and unshelled, and served as a confection after having been prepared by dipping in chocolate or in fondant; and sundry other features illustrating the work of the division.

During the few months preceding the fair, the attention of the horticulturist was directed chiefly to activities of the several committees on fruits, vegetables, field crops, and flowers. This year, in connection with the prize contest conducted by the Honolulu Star-Bulletin with the cooperation of the department of public instruction, he again acted as one of the judges of school and home gardens of the

children on the island of Oahu. It is gratifying to be able to record that since this work was begun there has been a marked improvement in the gardens both at the schools and at the homes. Some of the children walked miles in order that they might take advantage of the plats available for their gardens; in some cases, not only tools and manure were carried long distances, but daily trips were made so that the plats might receive watering and other cultural attention, and many young people carried the produce on their backs to a suitable marketing place.

The writer, while on a trip to the island of Hawaii, elsewhere referred to, made observations on the progress of the island's food production, and gave demonstration lessons in budding and grafting to some of the collaborators of the station and to others who would impart the knowledge. An increased interest in food production work was aroused among plantation owners, and laborers, homesteaders, and the planters of small holdings, and suitable opportunities presented themselves in many parts of the island for the further distribution of food crops, especially the selected varieties of sweet potatoes, cassava, edible canna, and papaya.

On the Parker ranch, at Waikii, splendid work in the production of about 3,500 acres of first-class corn was accomplished, and Mr. A. W. Carter, the manager, estimates the weight of corn produced equal to the entire importation of wheat flour in Hawaii during the last year.

It was noted that all along the Hamakua coast and in Kona plantings of upland taro were being made as rapidly as it was possible to secure this stock for propagation; this bespoke interest and enthusiasm in a material which had not only advanced in price, but was hard to secure.

One of the most interesting observations in Kona was that of the successful growing of squashes, pumpkins, watermelons, and even muskmelons. For the last 20 years it has been impossible to grow muskmelons or cantaloups in the Territory because of the devastations which resulted from attacks of the melon fly. The parasites introduced to control this insect have proved a success in this respect. Entomologists attribute the fact to prevailing excellent conditions which tend to aid its work. In almost every part of the district there is found a cucurbitaceous vine known as the wild cucumber (*Momordica charantia*), the fruit of which acts as a favorite host for the melon fly. Fortunately, it is a fruit into which the parasite can penetrate and find the larvæ of the fly. This wild plant functions as a trap into which the melon fly lays its eggs, which are destroyed in a later stage of their development.

The Kona orange is again coming into its own after having suffered from scale-insect and fruit-fly attacks. Citrus trees thrive very well

in Kona. In fact, it is doubtful whether any other part of this Territory gives greater promise for the successful cultivation of the finer varieties of oranges, grapefruits, lemons, and limes. It would be worth while to increase the planting of all of these kinds of citrus in Kona.

The station is confining the distribution of seeds and plants, as far as possible, to a few sorts which it has produced, or to those considered most important for general growth, and which can not be readily obtained elsewhere. Many thousands of seedlings of the station variety of tomato bred as a resistant to the melon fly, and an equally large number of papayas of the station variety were distributed. The practice of the station has been to disseminate seeds of these new varieties rather than the plants, except where only a few plants can be grown, as on small city lots.

The burden of extension-service work was further enhanced by a daily increasing number of telephone and letter inquiries for information covering a wide field of horticultural and related subjects.

REPORT OF THE CHEMICAL DIVISION.

By Maxwell O. Johnson and Kim A. Ching.

As food shortage conditions prevailed during the greater part of the fiscal year, the chief work of the chemical division consisted of studies of means and methods for the preservation and utilization of food. Experiments were made in drying and canning local fruits and vegetables. Investigations covering the manufacture of starch from a number of different local sources were made, and the manufacture of vinegars received much attention. Vinegar, which when tested surpassed the required local standard (4 per cent acetic acid), was successfully made from pineapple juice. A number of analyses were made of home-grown feeding stuffs and of soils, and an extensive fertilizer experiment with bananas was started. The investigations on the biochemical effect of manganese were continued.

DRYING HAWAIIAN FOOD PRODUCTS.

During the past fiscal year experimental work in drying was greatly facilitated by the completion of a large tower drier and the installation of a small vacuum drying system. The tower drier holds trays 3 feet wide by 4 feet long. A blower, driven by a small gasoline engine, forces air around steam coils and up through the trays in the tower. Regulation of temperature can be had by varying the number of steam coils used, and by altering the steam pressure. The velocity of the air can be controlled by changing the speed of the blower. Experiments were run on a semicommercial scale with this drier and

satisfactory results were obtained. In the following table is shown the percentage of dried fruit and vegetables obtained from the tower drying system:

Yield of dried fruit and vegetables produced in tower drier.

Materials.	Weight of original.	Weight of peeling.	Weight of peeled root or fruit.	Weight of dried product.	Dried material from original.	Dried material from peeled root or fruit.	Moisture loss.
	Pounds.	*Pounds.*	*Pounds.*	*Pounds.*	*Per cent.*	*Per cent.*	*Per cent.*
Sweet potato	200	$39\frac{3}{4}$	$160\frac{1}{4}$	53	27.0	33	67.0
String beans	10	....	....	$1\frac{1}{2}$	14.4	....	85.6
Carrot	$8\frac{1}{4}$	....	....	$1\frac{1}{4}$	15.1	....	84.9
Turnips	$5\frac{3}{4}$	....	....	$\frac{1}{2}$	7.6	....	92.4
Cabbage	8	....	....	$\frac{7}{8}$	11.2	....	88.2
Cucumber	$9\frac{1}{8}$	....	....	$\frac{7}{16}$	4.8	....	95.2
Pineapple	38	10	28	$5\frac{1}{8}$	13.4	18.3	81.7
Papaya	$8\frac{1}{8}$	$1\frac{1}{8}$	7	$1\frac{5}{16}$	11.5	13.4	86.6
Mango	$7\frac{1}{2}$	*a* $4\frac{7}{8}$	$2\frac{5}{8}$	$1\frac{3}{4}$	23.3	66.6	33.4

a Peeling weight, $2\frac{1}{8}$ pounds; seed weight, $2\frac{3}{4}$ pounds.

PRESERVING HAWAIIAN FOOD PRODUCTS.

A number of unsuccessful attempts were made to preserve the avocado fruit, as when heated, to sterilization temperature, the fruit developed a very bitter disagreeable flavor. The best method employed so far was that of cutting the peeled halves into small cubes, handling them meanwhile as aseptically as possible. After this the cubes were placed in a sterilized jar, which was filled with an ordinary commercial tomato cocktail sauce heated to the boiling point. Avocado preserved in this manner has kept in good condition for a year.

Papayas may be preserved in a manner similar to the avocado, or the two fruits can be combined.

Experiments were also made in the utilization of pineapple juice, which is a waste product of the canning industry. By mixing and boiling down equal parts of clarified pineapple juice and guava extract, a very good jelly, which was considered greatly superior to ordinary guava jelly, was obtained. Pectin precipitated from guava extract by alcohol and added to pineapple juice made a good jelly after being boiled down. Experiments were made in concentrating pineapple juice by freezing. This method, which gave good results, consisted in freezing the juice in an ice-cream freezer and separating the concentrated juice by centrifugal action.

MANUFACTURE OF STARCHES.

An attempt was made to manufacture starch from pineapple stumps. Extraction of the starch was made by grating the stumps, which contained many hard fibers. Because of a slowness in settle-

ment, due to the fineness of the starch grains, some trouble was experienced in separating them from darker woody particles. About 2.5 per cent of starch, based on the weight of the stump, was obtained.

Starches were also extracted from the root crops of taro, sweet potato, edible canna, Irish potato, cassava, and from Guam corn, rice, arrowroot, banana, and tree fern. Results of these experiments are being prepared for publication in bulletin form.

MANUFACTURE OF VINEGARS.

In a previous report of this station[9] a former chemist stated that experiments with pineapple juice were made for the manufacture of vinegar, but that it was found impossible to make a product which would comply with the legal standard requirement for acidity.

Experiments with pineapple vinegar were conducted during the past fiscal year. A pineapple juice, testing 11° Brix, was secured from one of the pineapple canneries. This was heated to boiling, poured into a carboy plugged with cotton, and, on the following morning, inoculated with common bread yeast. Very active fermentation took place, and by the third day the juice had settled. Samples taken on the fifth day showed an alcoholic content of 5 per cent. The product of fermentation was a cider-colored clear liquid which was poured off from the settlings. After some difficulty was experienced in obtaining active vinegar bacteria, a fairly active cider vinegar was secured and mixed with the fermented juice in parts of 1 to 4 and 1 to 8 of the juice. The mixtures were placed in glass vessels having cheesecloth covering. Two and a half months later a very active vinegar fermentation had taken place and a heavy layer of mother of vinegar had formed. The mixture of 1 part to 4 of juice contained 4.2 per cent of acetic acid, and was pronounced of fine quality by local experts. There should be no longer any difficulty in the manufacture on a commercial scale of vinegar from pineapple juice, especially now that active cultures of vinegar bacteria have been secured, and a quick process can be had by means of vinegar generators.

ANALYSES OF FEEDING STUFFS.

The following analyses have been made as the result of considerable interest manifested in the development of local sources of supply of feeding stuffs:

[9] Hawaii Sta. Rpt. 1913, p. 34.

Chemical analyses of some Hawaiian feeding stuffs.

Feeding stuff.	Water.	Ash.	Crude protein.	Carbohydrates.		Fat.
				Fiber.	Nitrogen-free extract.	
	Per cent.	*Per cent.*	*Per cent.*	*Per cent.*	*Per cent.*	*Per cent.*
Pigeon pea meal (stem, leaves, and pods)	11.9	2.96	9.21	38.73	34.53	2.67
Coconut meal	10.7	6.09	17.15	11.14	44.13	10.79
Fiber from pineapple stump after starch extraction	10.83	.91	3.5	15.12	68.98	.66
Mixed feed	13.31	8.11	8.57	12.58	54.64	2.79
Brazilian velvet-bean meal (stem, leaves, and pods)	10.20	6.48	6.21	12.69	62.91	1.51
Fiber from good pineapple plant after extraction	9.73	2.07	3.67	17.20	65.74	1.59
Sisal stump	76.7	1.29	.35	7.07	14.26	.33
Cane top meal	7.05	5.85	4.72	31.48	50.05	.85
Alfalfa meal	8.37	3.89	14.86	28.88	41.63	2.37
Mung bean (*Phaseolus radiatus*)	13.06	3.88	24.67	4.41	52.68	1.30

FERTILIZER EXPERIMENTS WITH BANANAS.

During the past three years fertilizer experiments with bananas were carried on; solutions containing fertilizing salts were used as sprays, and various mixtures of the more insoluble fertilizers were applied to the axils of the leaves. In March, 1919, a new planting of about 5 acres was made at Mokuleia, Oahu, and utilized as a large fertilizer experiment. Most of the fertilizer experiments were based on the triangle system which seems to be one of the best methods proposed for this purpose.

The first application of fertilizer was made in April, 1919, and it is planned to make this experiment continuous so that results will be secured on successive ratoon crops as well as on the first crop. Should a fertilizer producing good results be secured, it will be of great benefit to the grower, who profits principally from the shipment of large bunches of bananas, the smaller bunches being of little commercial value.

FERTILIZER EXPERIMENTS WITH PINEAPPLES.

Fertilizer experiment on pineapples, mentioned in last year's report,[10] made by applying various mixtures of the more insoluble fertilizers directly to the heart of the plants, is progressing and the plants are now producing fruit. Dried blood applied in this manner gave the best results, and a fine stand of fruit, superior to the check rows on either side, is developing. Fish scrap, which was applied in the same manner, produced very dark green healthy plants. Unfortunately, the last application was made at a time when some of the plants were budding and as a consequence the fruit was more or less distorted and injured. Steamed bone meal produced small but positive benefit.

[10] Hawaii Sta. Rpt. 1918, p. 24.

MANGANESE INVESTIGATIONS

In the report for 1918 [11] a description was given of an experiment on manganese soil to which sulphur, at rates of 500 to 3,000 pounds per acre, a red very acid soil at rates of 1 to 6 tons per acre, and bagasse soaked in strong solution of iron sulphate at various rates, had been applied. None of these soil treatments were successful in supplying iron to the pineapple plants, and those on the treated plats became chlorotic at the same time as the checks. After spraying the whole plat with the iron sulphate solution,[12] however, the plants became green and healthy in a short time. It is a fact worth noting that applications of iron sulphate to the soil, at rates varying from 500 to 3,000 pounds to the acre, were unsuccessful in preventing chlorosis, yet the spraying treatment in which considerably less than 50 pounds of iron sulphate per acre was applied to the leaves, promptly cured the chlorosis. The application of the iron sulphate to the soil was effected by soaking bagasse with the iron sulphate, then applying the soaked bagasse and incorporating it in the soil.

REPORT OF THE AGRONOMY DIVISION.

By H. L. Chung.

The agronomy division accomplished good work during the fiscal year 1919, dealing primarily with the emergency food crops for man and animal. The work covered included breeding, fertilizer experiments, variety testing, and distribution of planting stocks of new improved varieties.

CORN.

During the past year two varieties of corn. the Guam and the Cuban Red, have been under test at the station in Honolulu. They represented the two strains selected from a number of varieties for ideal type and yield. The Guam variety produced at the rate of 52.5 bushels to the acre in 1919, an increase of 5 bushels over the crop of 1917–18, while the Cuban Red yielded at the rate of 30.4 bushels.

The Guam variety was characterized by prolificacy, two or three ears appearing on a single stalk. Both varieties, however, were wanting in the desirable length of the ears. This defect, in large measure, was responsible for their low yield. It is thought that constant and careful selection will eventually result in ears developed to the desired length.

While the Guam corn appears to be one of the most resistant varieties to conditions as far as the leaf hopper in Hawaii is concerned, its market possibilities are and will be limited as long as the cosmo-

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[11] Hawaii Sta. Rpt. 1918, p. 24.

[12] Hawaii Sta. Press Bul. 51 (1916).

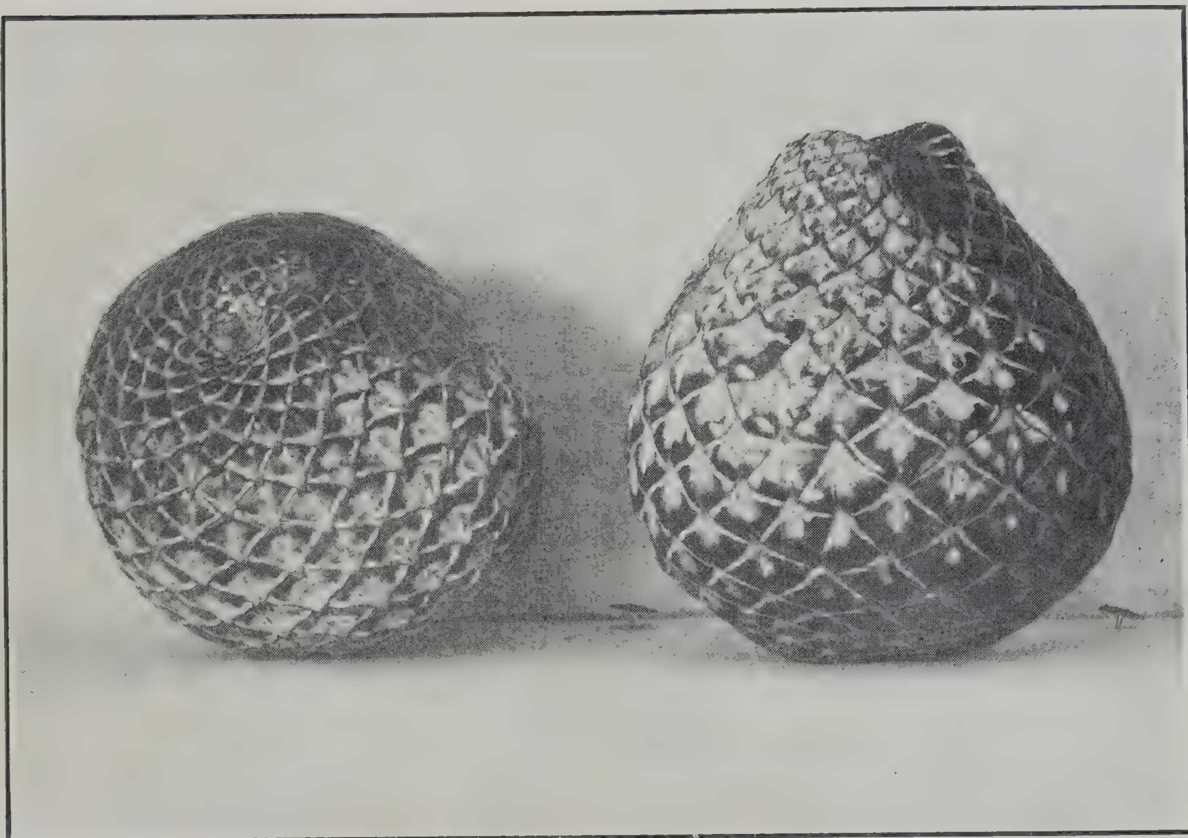

FIG. I.—FRUIT OF IVORY NUT PALM (CŒLOCOCCUS CAROLINENSIS).

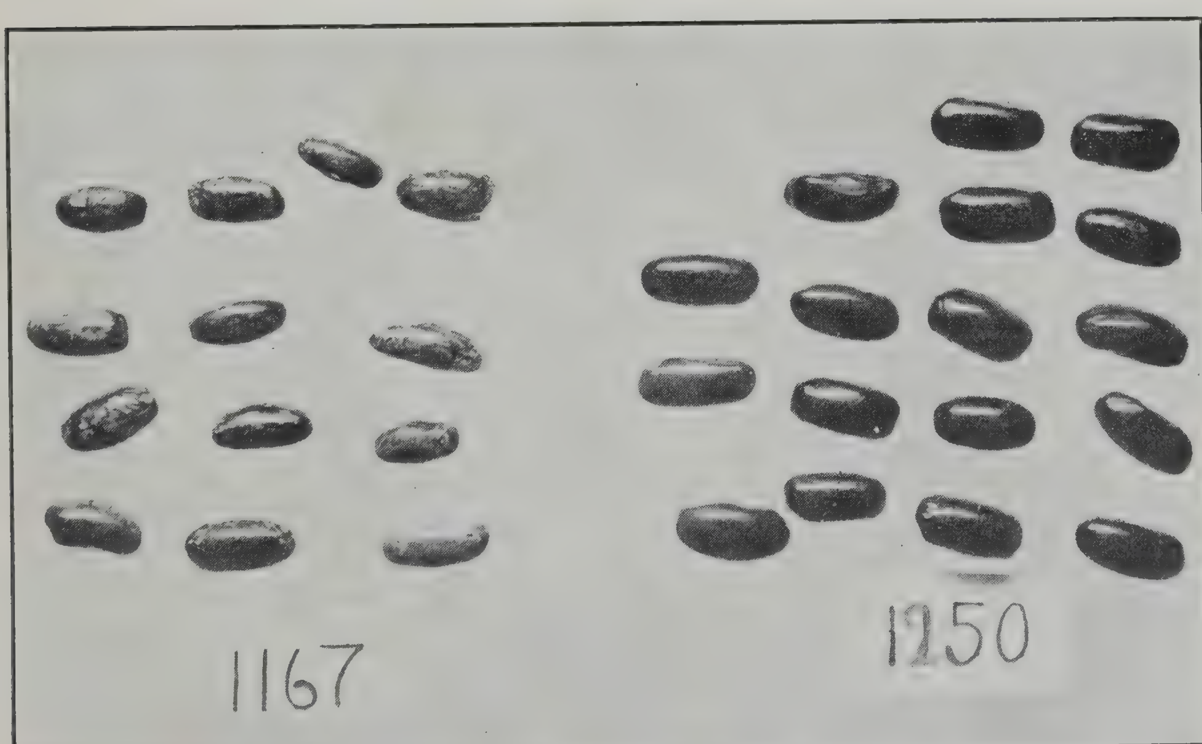

FIG. 2.—A BEAN MUTATION. ORIGINAL ON LEFT, MUTANT ON RIGHT. DARK BLUE GROUND COLOR SAME IN EACH. NO MOTTLING ON MUTANT.

FIG. 1.—A PROMISING SWEET POTATO HYBRID (C89A).

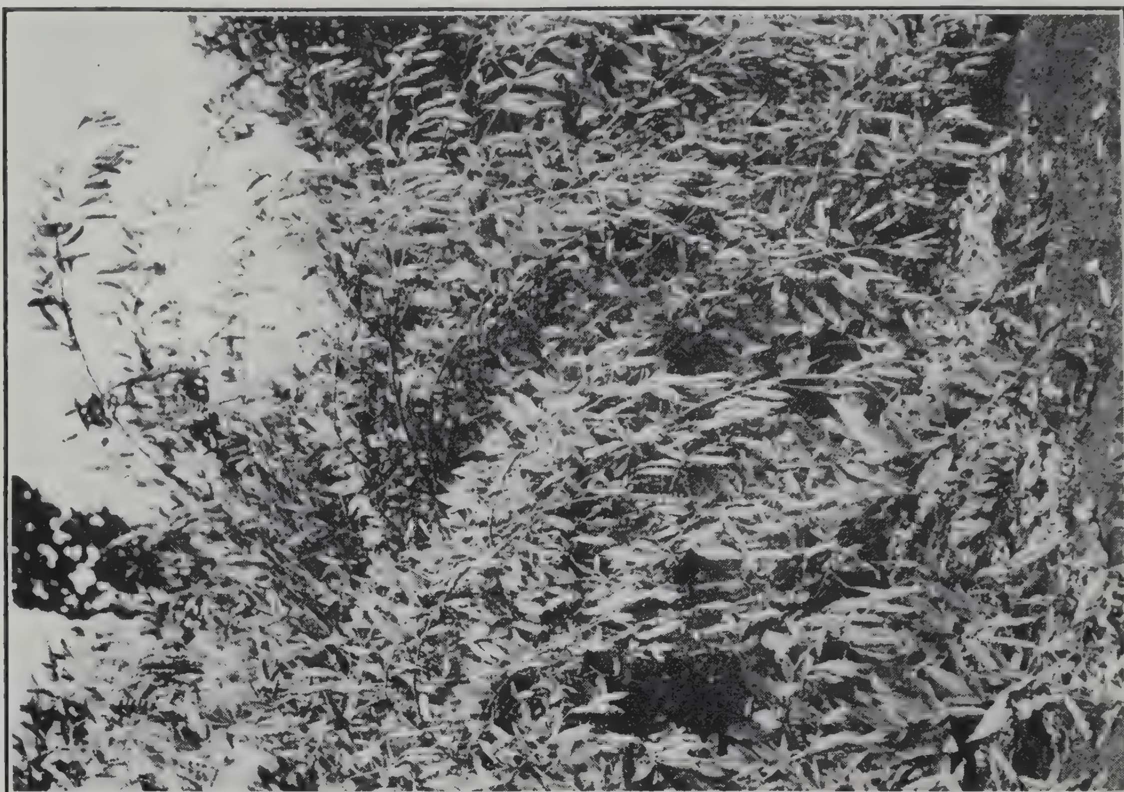

FIG. 2.—HEAVY PRODUCING STRAIN OF PIGEON PEA.

politan population demands a yellow corn. For this reason, the local markets rarely handle any white corn. Because of this peculiar condition the agronomy division is preparing to meet the demands of the future market by hybridizing the Guam corn with some yellow varieties in order to ultimately develop a yellow variety which will possess the desirable characteristics of the Guam corn.

CASSAVA.

A fertilizer experiment on a small scale was carried on in field N at the station. Results are not yet available as the plants are only in their tenth month of growth.

Varietal tests with cassava are also being conducted in the same field, the object being to introduce superior varieties. The tests consist of five varieties, imported from the Philippine Islands through the courtesy of P. J. Wester, horticulturist for the Philippine government, and four varieties from the mainland, selected personally by F. G. Krauss of this station.

The importance of the cassava as a root crop is exemplified by the number of its cuttings, which were distributed in lots of from one to two dozen to individuals. The value of the cassava as a carbohydrate feed for hogs is recognized, the hog raisers of Hawaii frequently requesting from one to nine thousand cuttings of the best varieties.

BEANS.

Since 1917 garden beans of different varieties have played an important rôle in the make-up of small backyard gardens and military company gardens. In fact, the bean was found so important that much time and care was devoted to developing heavy producing strains of the several varieties suggested by the emergency food crop program. Selected beans in lots of from 1 ounce to 1 pound are generally allotted to each applicant to whom the recommendation is made to allow one-half of the crop to go to seed.

Mutation in beans.—A mutation was observed among the Early Refugee variety, No. 1167, a strain harvested after its third generation of growth from selected seeds. The sport of a single plant was discovered among the 200 individual plants when undergoing further selection in the laboratory. Forty-seven of the sport beans were planted. In each generation, and for three successive generations, they reproduced beans identical with the original mutant in physical appearance. Both the parent and the mutant beans showed the same peculiar dark purplish ground work color not possessed by any other lot of beans under test. The dissimilar characteristics between the parent and the mutant (see Pl. V. fig. 2) are summarized as follows:

Dissimilar characteristics observed in beans of parent and mutant plants.

	Nature of growth of plant.	Color of fresh pod.	Color of matured bean.	Length of bean.	Width of bean.
				Inch.	*Inch.*
Parent	Bush	Olive green	Dark purplish blue with light orange mottling.	$\frac{1}{2}$	$\frac{3}{16}$
Mutant	do	Wax yellow	Dark purplish blue	$\frac{17}{32}$	$\frac{9}{32}$

Mr. E. J. Mooklar, formerly of this station, tested the edible quality of the sport bean and pronounced it very succulent and tender, when cooked, and one of the best edible-pod beans.

SWEET POTATO BREEDING EXPERIMENTS.

Preliminary work with sweet-potato breeding was begun in December, 1917. The object of this project was to create some new varieties possessing, among other desirable characteristics, early maturity as the predominant feature. While the parents used for this purpose had both good and bad qualities, the work was begun with the hope that by hybridizing certain individuals the desired characteristics could be obtained from some of their seedlings. However, the seedlings produced from the same seed pod revealed the fact that most of the parents used were multiple hybrids. In many cases where three seeds from the same seed pod were planted, three seedlings, each having a distinct leaf pattern, arose. The results expected from such seedlings may not, therefore, be in accordance with the actual realization. The present work gives every indication of promising results. Seedling C89A has proved to be a very prolific individual, having purple and white mottled flesh (Pl. VI, fig. 1). Seedling C111A as an edible is one of the finest varieties of sweet potatoes, being nonfibrous and very mealy.

MISCELLANEOUS CROPS.

Field turnips.—Plantings of the seeds of the round field turnip (*Brassica rapa*), the sample of which was received from Canton, China, were made 18 inches apart in 24-inch rows in field N. When harvested after a growing period covering 18 weeks, the crop gave a calculated yield of 43.5 tons per acre. Individual roots measured 12 inches in diameter and 9 inches in length.

Pigeon peas.—Work on pigeon peas was confined to the growing of seeds selected from high seed-yielding strains (Pl. VI, fig. 2) for general distribution among the poultry raisers. The peas serve as a substitute for corn and other grains commonly marketed as poultry feed.

Dry-land taro.—At the first Territorial fair in 1918 the taro exhibit demonstrated the several ways of successfully growing taro by adapt-

ing the plant to climatic and soil conditions of the different localities in Hawaii. The dry-land varieties attracted considerable attention among the homesteaders and landowners whose lands are non-irrigated. This station has received many requests from interested parties for dry-land taro for propagation purposes, but owing to the limited supply only a very small quantity was furnished to each applicant.

CASTNER FORAGE-CROP STATION.

On account of the unusual drought which prevailed at the forage-crop station at Castner progress with some of the introduced forage crops was retarded. In 1918–19 a rainfall of only 30.32 inches, compared with 58.56 inches of the previous fiscal year, was responsible for considerable retardation in the growth of all grasses. As a result some of these grasses died, while others have had a hard time to exist.

ROOT CROPS.

Cassava.—An extensive fertilizer experiment was instituted at Castner during the fiscal year 1918. The cassava was planted April 2, 1918, and will be harvested in September, 1919.

That the drought had a deteriorating effect on the plants is proved by the very poor growth of the cassava. The branches are undersized and the leaves are proportionately small.

Edible canna.—The edible canna was found to be desirable either as a soiling crop or a crop for starch production. Once the plant gets the proper start it will grow without need of further attention.

At Castner 8 plats with hills spaced at 3 by 6 feet were planted to this crop and after 14 months' growth the following data were secured:

Results of experiments with edible canna at Castner.

No. of plat.	No. of hills.	Plat yield.		Calculated acre yield.		No. of plat.	No. of hills.	Plat yield.		Calculated acre yield.	
		Tubers.	Tops.	Tubers.	Tops.			Tubers.	Tops.	Tubers.	Tops.
		Pounds.	Pounds.	Tons.	Tons.			Pounds.	Pounds.	Tons.	Tons.
1	4	68.75	40	20.79	12.1	5	4	63	46	19.05	13.89
2	4	73.75	47	22.35	14.21	6	8	104	76.75	15.73	11.6
3	4	68	40	20.57	12.1	7	4	74	40	22.38	12.1
4	4	62	43	18.75	13	8	4	77	47	23.29	14.2

Despite the dry weather the edible canna made a remarkable growth. In the company gardens the plant attained a height of 10 feet where irrigated.

Field beets and field carrots.—Where irrigation can be made available, these two root crops bid fair to become the succulent feed for horses and cattle of the Wahiawa district. The Giant White carrot

and Long Red mangel produced roots weighing 6 and 12 pounds, respectively, after a period of 10 months' growth without irrigation.

Potatoes.—The hot and dry weather made the planting of potatoes at Castner impracticable. When attempts were made to plant the Hamakua Hybrid variety under the unusual weather conditions, it was found that the cut potatoes were dried by the intense heat before they had a chance to sprout.

On May 23, 1919, seed potatoes, certified in New York to be blight resistant, were received by the pathological division of this station and turned over to the agronomy division for trial planting. Samples were distributed to the military company gardens for cooperative tests. At the time of this report (June 30, 1919), no sign of blight is to be observed on any of the plants.

LEGUMES.

Annual white sweet clover.—This clover (*Melilotus alba annua*) was sent to this station by Prof. H. D. Hughes, of the Iowa Agricultural Experiment Station, Ames, Iowa. A portion of the seeds was planted at the forage-crop station, where the plants spread well, made vigorous growth, and showed good seed-producing characteristics. This sweet clover will be planted on a larger scale at the station in Honolulu in order to determine its value as a feed for cattle and horses.

Alfalfa.—The attempt to grow alfalfa without irrigation at Castner was unsuccessful. It would be apparently impracticable and decidedly unprofitable for a farmer to try to grow alfalfa on a large scale without the aid of irrigation even in Wahiawa, the farming district immediately adjoining the reservation. The alfalfa at the substation is making very little growth on account of the extreme drought.

GRASSES.

The grass plat experiments at Castner were also handicapped by the extreme drought. Certain of the grasses are evidently drought resistant, since they remain green, yet their growth is stunted and their palatable qualities affected.

Several species of grasses which were adapted to Florida conditions were sent by Mr. J. B. Thompson, of the Florida Agricultural Experiment Station, Gainesville, Fla., for trial planting at this station. Unfortunately the seeds failed to germinate.

The Merker grass (*Pennisetum merkeri*), another grass received from Mr. Thompson, is not only growing very luxuriantly, but is stooling heavily. In physical appearance it resembles the Napier grass (*Pennisetum purpureum*). Data on the yield are not available at this time.

RAINFALL.

The following tabulation gives the comparative rainfall readings in inches for the past two years at the substation at Castner:

Rainfall at Castner substation for the fiscal years 1918 and 1919.

Month.	Year. 1918-9	Year. 1917-8	Month.	Year. 1918-9	Year. 1917-8
	Inches.	*Inches.*		*Inches.*	*Inches.*
July	1.9	1.3	February	0.85	5.8
August	3.9	.96	March	2.4	3.6
September	7.4	5.8	April	.19	9.8
October	1.1	3.6	May	1.1	1.9
November	5.8	3.4	June	1.8	5.8
December	2.9	9.3			
January	.98	7.3	Total	30.32	58.56

DISTRIBUTION OF SEEDS AND CUTTINGS.

During the fiscal year the agronomy division distributed seeds and cuttings to the emergency war gardeners, dairymen, and to ranchers. For the 12 months ending June 30, 1919, seeds and cuttings were distributed to 425 applicants in amounts as follows:

Seeds and cuttings distributed during year ending June 30, 1919.

Crop.	Seeds.	Cuttings.	Crop.	Seeds.	Cuttings.
	Pounds.	*Number.*		*Pounds.*	*Number.*
Alfalfa	32		Sorghum	53	
Beans	107		Cassava		34,529
Corn	480		Uba cane		3,324
Grass seed and cuttings	1,056		Edible canna		5,058
Pigeon peas	72		Napier grass		1,412
Dry-land rice	25		Sweet potatoes		12,771

REPORT OF THE DIVISION OF PLANT PATHOLOGY.

By C. W. Carpenter.

The division of plant pathology during the fiscal year 1919 continued the program of work set forth in the 1918 report. The Territorial county agents and other extension agencies cooperated with the division, and the pathologist, thus greatly relieved from the burden of extension and demonstration work on insect and disease control, was enabled to devote considerable time to investigation and experimentation activities. With the close of the war it was again found practicable to give attention to important research problems in which immediate practical results were less certain. The manuscript of a bulletin entitled "Potato Diseases in Hawaii and Their Control"[13] was submitted early in the fiscal year for publication.

[13] Hawaii Sta. Bul. 45 (1920).

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TARO ROT.

A preliminary study of the disease reveals the fact that there are several forms of taro rot present in Hawaii. The grayish to brownish rot of the taro corm (the edible underground portion variously called root, tuber, bulb, etc.) is by far the most common and destructive type in the field. The appearance of the affected taro varies considerably, sometimes being gray, soft, and mushy like poi, and at other times more dry and firm and grayish in color, or having merely a brownish discoloration of the tissues adjacent to the large root fibers which traverse the corm. Pathological culture studies of taro rot as it exists in the corm while still in the soil has resulted in the isolation of a predominant organism which resembles *Pythium debaryanum*. Since this latter organism is generally considered responsible for a number of other vegetable rot troubles in moist situations and under favoring conditions,[14] is a parasite of no mean capabilities, there is every indication that this species or a near relative is the cause of the common form of taro rot. It has been previously noted[15] that this organism was found associated with a root rot of rice in Hawaii. A preliminary inoculation experiment with the taro organism resulted in rot of the inoculated taro, while in no case did the uninoculated but otherwise similarly treated taro develop rot (Pl. VII, fig. 1). The taro, kept in moist chambers, sprouted vigorously during the time of rot development, a fact which would indicate continued vitality. Furthermore, that the development of the organism is accompanied by the formation of an enzym is evidenced by changes of the tissues several centimeters distant from the point of inoculation and beyond a point where the organism can be recovered. In the only experiment of this kind attention was directed to these deep and distantly affected tissues and an attempt made to isolate the uncontaminated parasite resulted in failure to obtain the organism.

The organism *Sclerotium rolfsii* was found associated with a rot which occurred in taro several days after it was pulled. Further investigation on the causes of taro rot will be carried on at the first favorable opportunity.

A circular letter on taro rot, furnishing available information to taro growers, was prepared by the pathologist.

Taro rot investigations on Molokai.—A survey of the valley of Halawa, island of Molokai, showed the taro growing there to be in a precarious condition, owing to the presence of a taro rot disease. The rot was of the type previously mentioned as associated with the organism *Pythium debaryanum*. It was thought that conditions would be improved by letting the taro lands rest awhile, or by the

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[14] Hawkins, L. A., U. S. Dept. Agr., Jour. Agr. Research, 6 (1916), No. 17, pp. 627–639.

[15] Hawaii Sta. Rpt. 1918, p. 43.

practice of crop rotation. However, the suggestions of resting the patches, rotating with rice, or even plowing and harrowing after drying them out, met with little enthusiasm among the planters who make their land serve as the chief means of livelihood. As a result of continuous cultivation covering a long period, the soils have become very acid and otherwise unfavorable to the crop, but it is believed that this condition can be best corrected by plowing up, aerating, and resting the lands, or by planting them to other crops. Since there was no inclination to practice either method, applications of lime were recommended as a practicable way to ameliorate the existing conditions. A small demonstration experiment, carried on in cooperation with the trustees of the Bernice P. Bishop estate, was started on land of that estate in Halawa, in which tests with applications of lime, coral sand, and fertilizer were made. The selected land was a taro patch which, for several years, had grown very little marketable taro, most of which was more or less decayed when pulled up.

Mr. C. C. Conradt, of Pukoo, Molokai, consented to represent the experiment station in looking after the experiments in Halawa, in addition to acting as collaborator for this station on Molokai, where there is no regular county agent. Data on the results of the experiments are not yet available.

SPRAYING TO CONTROL THE BANANA FRECKLE DISEASE (PHOMA MUSÆ).

The banana freckle disease, described in the 1917 and 1918 reports of this division,[16] continued to do serious damage to the banana industry. As previously noted, this disease affects almost exclusively the Chinese or dwarf banana (*Musa cavendishii*). The disease spots the leaves and fruit; the former prematurely dry and fall, resulting in a general weakening of the plant; the latter appear blackened and disfigured, and unevenly ripen in small bunches.

The larger plantings at Mokuleia, where the bulk of the best fruit is grown, were so threatened by the disease that drastic methods were undertaken in a 100-acre plantation in an effort to check its progress. The pathologist is deeply indebted to Mr. A. J. Campbell, who not only made this cooperative project possible, but maintained throughout the work a keen personal interest and submitted valuable suggestions thereon. The campaign consisted of pruning the trees and burning the affected leaves, removing the upper portion of the stump when a bunch was cut to lessen the infection of the suckers, pulling out the worst affected and otherwise undesirable plants from about 25 acres, and planting cane therein. The more desirable younger fields were retained and sprayed with a fungicide. In the

[16] Hawaii Sta. Rpts. 1917, pp. 40, 41: 1918, pp. 36–39.

spraying work, attention was directed particularly to the upper surfaces of the leaves.

Preliminary experiments showed that Bordeaux mixture would not spread well on the waxy leaves, nor would the lime-sulphur spray. The addition of resin sal soda sticker to Bordeaux mixture, however, proved very satisfactory in overcoming the difficulty. The formula for Bordeaux applied generally in the work is that known as the 4:4:50 formula, though the 4:3:50 and the 5:5:50 formulas were applied to certain plats by way of experiment. The resin sal soda spreader sticker is prepared by boiling 1 pound of resin and one-half pound sal soda in 2 quarts of water until the proper degree of combination is effected. Subsequent experimentation with this formula and others showed that a more workable mixture resulted if the combination was as follows: 4 pounds resin, 2½ pounds sal soda, and 2 gallons of water. Two quarts of the sticker was used with each 50 gallons of Bordeaux.

The Bordeaux mixture was applied with a 100-gallon capacity sprayer, equipped with two lines of spray hose 200 feet long, in 50-foot sections, so that desirable combinations could be readily used, depending on the distance of the plants from the sprayer. (See Pl. VII, fig. 2.) Eight-foot extension rods and small-capacity side-outlet cyclone nozzles were found practicable. Since a relatively long time must be spent on each plant in order to reach the leaves at the proper angle, the small-capacity nozzles were found to give more satisfaction than the larger ones. Temporary roads were constructed wherever needed through the plantation, and portable bridges were made for crossing irrigation ditches, etc.

It was found to be impracticable to thoroughly prune out all infections with a crop like bananas, since plants of various ages were affected, the young suckers becoming infected from the old plants, etc. Too extensive cutting of leaves of plants was found harmful to the fruit, and when attempted on rather young plants, the pseudo-stem later developed such a constriction at the top that the bunch could not issue normally; assisting the bunch to emerge did not result in any material improvement. A similar effect resulted from the pruning brought about by the premature falling of the leaves. It was found, however, that a few leaves could safely be removed, though it was rather difficult and almost impossible to teach the Chinese laborers the discrimination necessary.

As a result of eight months' prosecution of the pruning and spraying campaign on this plantation, there is every indication that the method will be a successful one. The plants throughout are looking very much better than when the campaign started. Conclusions either as to the effectiveness or practicability of the method can not be determined definitely at this time.

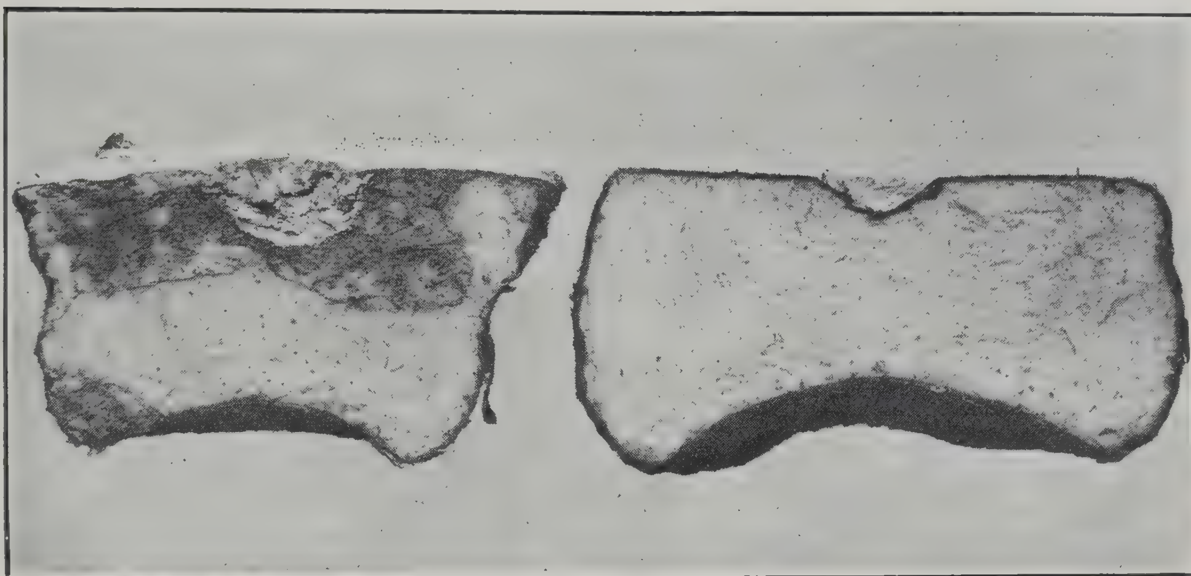

FIG. 1.—TARO ROT DISEASE DUE TO FUNGUS OF PYTHIUM DEBARYANUM TYPE. INOCULATED ON LEFT; CHECK ON RIGHT.

FIG. 2.—SPRAYING BANANAS FOR CONTROL OF FRECKLE DISEASE.

FIG. 1.—CONTROL OF MITE DISEASE OF PEPPERS. SPRAYED WITH LIME SULPHUR ON LEFT; NOT SPRAYED ON RIGHT.

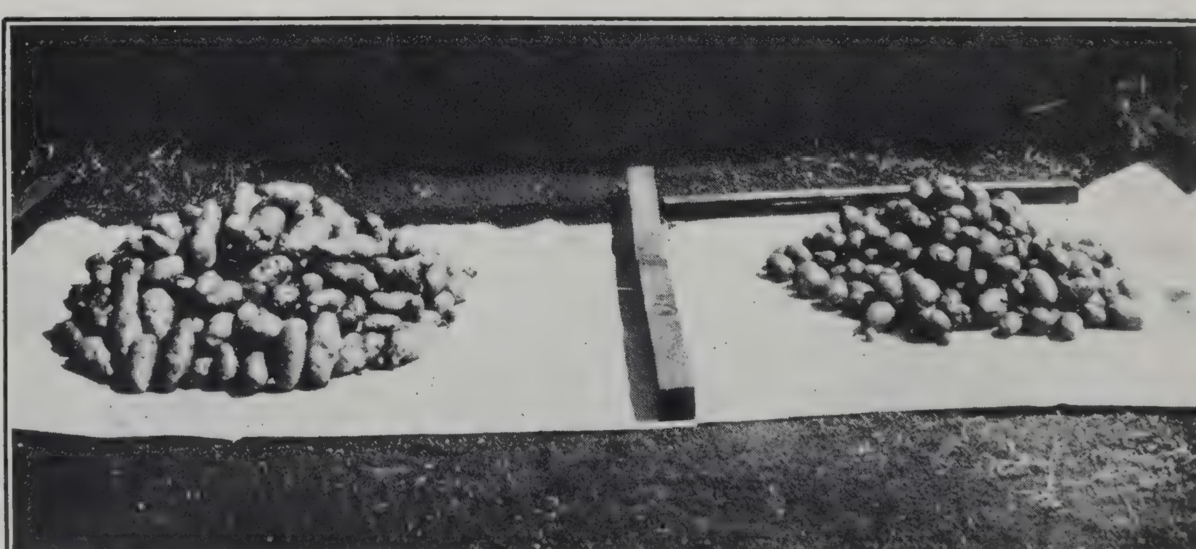

FIG. 2.—CONTROL OF MITE DISEASE OF POTATOES. SPRAYED WITH LIME SULPHUR ON LEFT; NOT SPRAYED ON RIGHT.

Recommendations to prevent the spread of this disease to other banana growing countries were made to the Territorial representative and inspector of the Federal Horticultural Board, and are being well carried out. Since the disease was observed on no island other than Oahu, suggestions were also made to the Territorial inspector to put into force certain restrictions regarding the transfer of banana suckers from Oahu to the other islands.

A MITE DISEASE AFFECTING SWEET PEPPERS.

A peculiar disease condition was noted on sweet peppers growing in dry and hot situations, and is characterized by the curling and stunting of the young leaves and buds. Though little attention has been focused on the disease, examination shows the symptoms to be practically the same as those previously noted[17] associated with mite infestation in the potato and tomato. Numerous mites are present, and the disease and its cause seem to be the same as that known as the potato mite disease. A small experiment carried on with diseased sweet peppers showed that applications of sulphur or lime-sulphur spray controlled the disease affecting them as well as that affecting potatoes. (See Pl. VIII, figs. 1 and 2.)

NEW ROOT-ROT PROJECT.

During the fiscal year the pathologist observed the presence of several very malignant diseases which call for immediate attention. As yet, however, their origin is more or less obscure, and while they have many conflicting symptoms and characters it is quite possible that some may prove quite identical in nature. Certain observations and work made to serve as a basis for a plausible working hypothesis were carried along the lines offering the most promise. This investigation, which is called the root-rot project, will include some studies on the microorganisms of Hawaiian soils.

MISCELLANEOUS NOTES ON PLANT DISEASES.

Among the microorganisms observed during the year and not noted in previous pathological reports are:

Sphærostilbe coccophila.—An entomogenous fungus, apparently parasitic on scale insects which infest the grapevines at Wahiawa, Oahu.

Sclerotium rolfsii.—A stem disease of peanut and affecting taro as storage rot.

Phytophthora colocasiæ.—Found in Oahu, Molokai, and Hawaii on taro leaves.

Cercospora bolleana.—Known as the fig leaf spot, and observed in Oahu.

[17] Phytopathology, 8 (1918), No. 6, pp. 286, 287.

Sphærotheca pannosa.—Rose mildew, found in Oahu.

Nematodes.—These organisms were found at Pearl City and Mokuleia, Oahu, associated with root rot accompanying the banana center leaf necrosis disease and chlorosis, noted in the 1917 report of this division[18]. In Oahu nematodes were also found associated with the root and crown rot of hibiscus.

REPORT OF THE POULTRY DIVISION.

By L. M. Ross.

During the past several years the major part of the poultry work of the station was conducted at the Glenwood substation, where, under Hawaiian conditions, single-combed White Leghorns were bred specially for egg production. During the past year, however, some attention was given to poultry investigations at the central station at Honolulu. This particular work was carried out with the following objects in view: (1) To ascertain the best system of feeding poultry in the Hawaiian Islands in order to obtain the highest practicable standards of egg production; (2) the development of methods for the most successful brooding and rearing of young poultry; (3) the development of the most effective methods for combating poultry diseases prevalent in Hawaii; and (4) the general encouragement and development of the poultry industry in Hawaii.

SOREHEAD OR CHICKEN POX.

The susceptibility of young chicks to the inroads of sorehead constituted in times past probably the most serious drawback to the successful production of chickens under Hawaiian conditions. Officials of the Territorial board of agriculture and forestry have to a considerable extent overcome this disease by their gratuitous distribution of the proper vaccine. It was found that prompt isolation of suspects, the careful attention to sanitary conditions, and one or two treatments with some suitable antiseptic to the heads of the quarantined birds resulted in reducing the damage from sorehead to negligible percentages. It is thought that unsanitary conditions are highly responsible for the development of conditions which are favorable for the spread of sorehead in poultry flocks. Foul and dirty quarters are probably the most important predisposing factors. In Hawaii certain poultry raisers pay special attention to the provision of sanitary quarters and yards for their flocks; and their young and adult stock have, as a consequence, been free from sorehead. It has been deemed advisable to procure from a breeder foundation stock which has not been subject to sorehead infection, so that this

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[17] Hawaii Sta. Rpt. 1917, pp. 36–42.

stock may not be a carrier of the disease. Strict sanitation should be practiced in such small matters as drinking vessels, roosting quarters, nest boxes, etc., and the poultry should be frequently transferred to fresh runs; the used runs should be plowed, dug, or planted to a crop in order to clean the ground. Where sorehead reached an advanced stage, calcium sulphid was found helpful. One tablespoonful of the powder mixed into a moist mash for each 25 hens should be fed daily until cure is effected.

POULTRY CANKER.

This disease is a very common one in Hawaii. In the course of a preliminary experiment, it was found that the following procedure ordinarily gives relief unless the disease has reached a far advanced stage. The ulcer, and portions of the flesh surrounding it—both inside and outside the mouth—must be painted with tincture of iodin immediately after the canker has been firmly compressed from the outside of the mouth; this compression will greatly eliminate the suppurated matter which is then ejected through the nostrils. Arrangements should be made to have handy a small pan, or other vessel from 3 to 4 inches deep, filled with kerosene oil. Into this kerosene the beak and nostrils of the chickens should be dipped, the head being held there for a few seconds. This operation should be repeated at least three or four times, after which a 1-grain capsule of quinine should be administered to each fowl. If this method of procedure be followed three or four days in succession, the canker will disappear and the chickens will be cured.

COMMERCIAL ASPECTS OF THE POULTRY INDUSTRY.

At the present time the poultry industry in Hawaii is relatively in its infancy, nor is it felt that much increase in the production can be expected until the poultry possibilities are thoroughly demonstrated on a practical scale, and the various drawbacks which now beset the average poultry raiser are overcome. Available statistics show that during the year 1917 some 497,261 dozen eggs, valued at $186,691, were imported into Hawaii from California; during the same year 77,090 dozen, valued at $15,132, were imported from foreign countries, chiefly from China. These figures clearly show that Hawaii holds great possibilities for the disposition of the product of increased poultry flocks in the islands.

REPORT OF THE EXTENSION DIVISION.

By F. G. Krauss.

Hawaii produced more food and feed stuffs during that period in which the United States was at war than during any equal period in her history. The agricultural extension division rendered every assistance to the work of stimulating and increasing this production. Throughout the war period close and active cooperation was maintained with the Federal and Territorial Food Administrations. The station's available agricultural data and the demonstrations conducted by it were always at the disposal of the Territorial county agents. Cooperative contacts were maintained with the Territorial agencies at all essential points, a fact which it is thought proved an effective factor in contributing to the excellent results achieved by the islands throughout the war period.

During the months of December and January a trip was made to the mainland of the United States, the journey covering ground as widely separated as California to Massachusetts and Florida. The major object of the trip was to obtain data regarding the production and utilization of cassava, but it was also found possible to get in close touch with the extension activities under way in several of the representative States, and in the United States Department of Agriculture at Washington, D. C. Collections were made of the data descriptive of the most successful methods along extension lines with the idea of adapting them to the peculiar conditions present in the Hawaiian Islands.

EXTENSION SERVICE WORK.

It is felt that a real service was rendered by the division in acting as middleman between the producer of food crops and those sources of information which gave any promise of being helpful to the producer. During the last 15 years cumulative and rather valuable agricultural information was gleaned from the various agricultural institutions and activities of the islands by the superintendent of the extension division. This information was placed at the service of interested parties at the experiment station library, the extension service library, and elsewhere.

In a number of instances plans were prepared for planting and for crop rotation, and working drawings were made for the construction of locally made farm implements, and even for farm buildings and for silos.

The attempt was made to maintain at all times a supply of seed, cuttings, and tubers, etc., of all the improved varieties of crops the increased utilization of which was recommended by the extension division to the island farmers. During the year improved planting

stock sufficient for over 1,000 acres was distributed. A large portion of the 40 acres under cultivation was devoted to the production of improved strains of seeds and planting material. Germination and purity tests of seeds were made for those requesting them.

The extension division was also instrumental in arranging for the distribution of approximately 100 young registered Berkshire pigs; this distribution was made at prices which not only enabled the farmer of limited means to purchase the pigs, but also enabled him to secure a foundation stock of superior breeding.

Extended trips through the principal islands were made during the year. By this means close contact was maintained with the more important diversified agricultural projects. Lectures on timely agricultural topics, and demonstrations of spraying, budding and grafting, home curing of pork, and caponizing, were held whenever an opportunity presented itself. Numerous timely articles were prepared for the local press. These articles have always met with a generous and prompt response from the public, and seem a most effective way of reaching the public at large. A neighborhood reading service was in active operation throughout the year. The various agricultural journals received by the extension division were pooled with those subscribed to by others and the entire collection was placed where it could benefit all. Extra copies of agricultural bulletins, etc., which were received by the extension division, were likewise passed along to those interested.

COOPERATIVE EXTENSION ACTIVITIES.

Cooperative relationships were maintained with the other divisions of the Hawaii Experiment Station as well as with the various Territorial and private agricultural institutions. Extensive feeding tests were carried on in cooperation with one of the larger agricultural companies, and, in a number of places, cooperative experiments and demonstrations dealing with special crops or improved agricultural practices were inaugurated. The various local agencies responsible for the school-garden contests, home-garden work, etc., continued to receive the active support of the extension division, as did also the Maui pig club. The superintendent of extension served as one of the judges for the school and home garden contests, and as chairman of the pig-club committee. Likewise, he cooperated actively as a member of the committee of Maui County for the second Territorial fair in Honolulu, and was appointed chairman of the agricultural committee for the Maui County Fair to be held in the autumn of 1919.

The work done in connection with the collaborators constitutes an important phase of the cooperative activities of the division. The collaborator, who represents the division among the farmers of the

particular neighborhood in which he is located, ordinarily owns, or, at least manages, the farm on which he works, while the demonstrations conducted by him are usually incidental to his major agricultural operations. During a whole or a part of the year there were four collaborators on the island of Hawaii, two on Kaui, two on Maui, and one on Oahu.

In cooperation with the Territory of Hawaii, the extension division is operating a demonstration farm unit in the newly opened homestead tract on the slopes of Haleakala. The object of this farm is to demonstrate, in the shortest possible time, just what can be profitably produced under the somewhat peculiar conditions of soil, rainfall, elevation, and exposure to winds. The homesteaders rendered very valuable assistance in breaking up the land, while the adjoining ranch generously assisted in the matter of fence construction. The Territorial legislature appropriated money for a small set of buildings, the money to come from the loan fund when there shall be a sufficient balance in said fund to make the outlay practicable.

EXTENSION ACTIVITIES AT THE TERRITORIAL FAIR.

The second Territorial fair at Honolulu offered unusual opportunities for exhibits of the most promising agricultural developments which resulted as an outcome of the intense wartime agricultural activities. The division was largely instrumental in stimulating active and enthusiastic interest among the numerous exhibitors and it entered about 75 individual exhibits, which showed a wide range of products raised on the Haiku demonstration and experiment farm.

One of the principal features of the exhibit of the extension division was its collection of various home-grown feeds suitable for grinding and mixing. This feed was displayed not only to serve as well-balanced rations for every class of live stock, but each feed, in the mixtures designed, was also properly proportioned to suit the needs of the different animals. (See Pl. IX.) It was shown that for various classes of live stock it is practicable to produce and mix home-grown feeds which not only furnish a palatable balanced ration, but which also can be produced at approximately half the cost of equivalent imported feeds.

ENLARGEMENT OF EXTENSION ACTIVITIES ON THE ISLAND OF HAWAII.

Although four collaborators were maintained on the island of Hawaii in connection with the work of the Glenwood substation, it is realized that even a larger working force is required to cover the agricultural work of the largest island in the group. This need was manifested especially when the Territorial legislature withheld its

financial support from the county agent system which developed during the war. On April 1, 1919, R. A. Goff, who has for some years been in charge of the substation at Glenwood, was appointed extension agent for the island of Hawaii. He had previously acted in this capacity in cooperation with the Territorial food commission for the region adjacent to Glenwood, as well as collaborating in the extension work of the station.

J. E. Gamalielson, one of the collaborators on Hawaii, is an active poultry raiser and serves as secretary of the Glenwood Creamery Co., a cooperative organization of farmers who market their butter through this agency after supplying local demands. A summary of the creamery business for the last year by months is given below:

Summary of business of the Glenwood Creamery Co. for the year ended May 31, 1919.[a]

Month.	Amount of butter marketed.	Average price per pound.	Total returns.	Cost of marketing.	Month.	Amount of butter marketed.	Average price per pound.	Total returns.	Cost of marketing.
1918	*Pounds.*	*Cents.*			1919.	*Pounds.*	*Cents.*		
June	340	57	$193.68	$10.24	January	358	70	$245.28	$14.32
July	429	54.4	237.65	13.88	February	322	63.04	203.02	12.24
August	402	56	224.94	14.24	March	554	61.37	334.47	15.36
September	420	57	239.26	14.16	April	427	65	277.44	13.44
October	353	57	202.00	13.48	May	435	67	291.45	14.28
November	185	57.8	106.92	7.24					
December	219	70.73	154.89	8.56		4,445	61	2,720.00	[b] 151.44

[a] A summary for the preceding five years was given in Hawaii Sta. Rpt. 1918, p. 28.
[b] About $5\frac{1}{2}$ per cent.

On the farm of Mr. Gamalielson, at Kaumana, Hilo, Hawaii, a flock of about 300 laying hens is maintained not only as a part of the regular business, but also as a demonstration of the possibility of a regular supply of eggs. The production of eggs, by months, is given below:

Egg production for the year ended May 31, 1919.

Month.	Number of eggs produced.	Month.	Number of eggs produced.
1918.		1919.	
June	2,496	January	4,404
July	2,754	February	4,389
August	3,536	March	5,182
September	4,491	April	4,401
October	4,440	May	4,129
November	3,280		
December	3,241	Total	46,743

From the above table it will be seen that there was an average production of 155.8 eggs per hen. The falling off in number of eggs produced in November and December was due to culling the flock.

NEEDS OF THE EXTENSION DIVISION.

Although the division has grown and flourished since its inauguration in 1914, it has many needs. A very apparent need is that of a well-trained marketing agent who not only would be able to attend to the various features of cooperative marketing organizations, but who would also stimulate active interest in farmers' organizations as a whole, as well as devote considerable time and attention to the further development of club work.

The islands also need the development of the farm bureau, which demonstrated its effectiveness throughout the mainland portion of the United States. A properly constituted farm bureau should be organized in every agricultural community throughout the islands, and should correspond in many ways to the chambers of commerce of up-to-date cities. Such an organization would greatly facilitate the work of the county agent, since it would bring him the counsel and advice of the more progressive farmers on the most pressing agricultural problems and their solution.

For the ultimate good of the islands, steps should be taken to increase such various organized projects as boys' and girls' pig clubs, potato clubs, corn clubs, etc. This class of work has heretofore been confined almost exclusively to school-garden work, and as a result of having received a great deal of attention from a number of different agencies throughout the islands, has been an unqualified success. It is felt, however, that the work should be made to embrace more than the production of vegetables; in fact, it should include the systematic raising of farm crops and animals as well. A promising boys' and girls' pig club was recently organized on the island of Maui.

Throughout the islands the ready responses to the home economics demonstrations occasionally made possible by various local agencies clearly proves the desirability of and the need for additional attention to this line of extension work. An efficient home demonstration agent visiting the more or less isolated homes of the island would impart a great deal of up-to-date information and, as an outside influence, serve to increase the happiness and efficiency characteristic of the average individual American home. Each county should have a county agent or full-time representative of the extension division.

HAIKU DEMONSTRATION AND EXPERIMENT FARM.

The Haiku demonstration and experiment farm was originally planned as a demonstration farm. However, a number of local problems developed which could be solved only by actual field and plat experiments. As a result, the experimental features of the work have developed in conjunction with those of the demonstration

activities until the two have acquired equal rank on the farm which serves as the base of operations for the extension division. Every theory of practice is first tried out on this farm before it is definitely recommended to the Hawaiian farmer. The practical nature of the demonstrations under way is evidenced by the increase in the number of visitors to the farm. Not only residents of the island of Maui, but also many people from all over the Territory were numbered among its interested visitors.

The experimental work consists in comparative variety tests of new and improved forage and food crops in order to determine their adaptability and possible advantages under local conditions. Cultivation and fertilizer experiments are designed to give definite information as to the best method to be followed for producing those crops which are found to be best adapted.

Another phase of the work is the growing of seed of these crops in order that the improved strains may be quickly disseminated throughout the island. The crops involved in the above work are as follows:

Crops grown at the Haiku demonstration and experiment farm.

Crops.	Number of varieties.	Crops.	Number of varieties.
Cowpeas	16	Grain sorghums	5
Culinary beans	4	Field corn	20
Pigeon peas	4	Popcorn	2
Peanuts	2	Sweet corn	2
Soy beans	12	Cassava	4
Velvet beans	2	Sweet potatoes	2
Alfalfa	10	Irish potatoes	8
Pasture grasses	2	Dry-land taro	20
Forage sugar cane	2	Japanese yam	2
Nonsaccharine sorghums	5	Edible canna	1

In addition to the above-mentioned work with crops, a number of experiments are under way to determine their utilization. The relative merits of the various crops under test are ascertained by feeding them to poultry, swine, dairy cows, and work animals belonging to the station. In addition to these experiments, milling and mixing tests of the various cured products of the farm are made with a view to establishing commercially practicable mixtures of Hawaiian-grown feeds as a substitute for imported feeds.

The hay crops are usually cured on portable curing trucks. The milling of cured hay and grains, including corn, Uba cane, sorghum, cowpeas, velvet beans, pigeon peas, peanuts, cassava, etc., and the mixing of the same to form balanced rations, constitutes one of the most practicable phases of the work and already has resulted in the local establishment of a large commercial milling plant for the manufacture of mixed feeds.

Variety tests, fertilizer experiments, and breeding work with corn.—The work with corn which was inaugurated in 1915, shortly after the establishment of the demonstration and experiment farm at Haiku, continued to broaden in its scope. In the breeding work another variety or strain of corn was developed to supplement the New Era 100-Day Yellow Dent. The new variety, which contains the same blood lines as the older type, possesses them in different proportions and requires a growing season of 20 days longer. This is a favorable feature for localities having ample rainfall.

When the writer was in Washington, D. C., during the past year, an experiment was arranged in cooperation with the office of Corn Investigations of the Bureau of Plant Industry, United States Department of Agriculture, to compare, by testing, a number of varieties of corn at different elevations with those already under test. The following mainland varieties are under test in direct comparison with the New Era 100-Day Yellow Dent and the local Kula type of corn: Mill Pond Prolific, S. P. I. No. 45903, U. S. Selection 119, Taxpan, No. 133, and Johnson's Prolific. These were planted at an elevation of about 500 feet at the Haiku demonstration and experiment farm, March 21–23, 1919. The corn, carried as No. 133, harvested June 25, was the only one having ears which matured during the fiscal year just closed.

The yield of No. 133, from a plat one-third acre in size, was at the rate of 40 bushels per acre, despite the fact that it was planted rather late in an unduly dry season. A second planting was made at the Haleakala demonstration farm at an elevation of about 2,000 feet, and a third planting was made at Waiakoa (Kula district) at an altitude of about 3,000 feet. These plantings are not yet sufficiently mature to justify any definite comparison.

In addition to the above-mentioned cooperative experiment, variety tests with the following varieties are being continued: Blount's Prolific, Casey's Purebred Old Virginia Shoe Peg, Virginia White Dent, Cocke's Prolific, Boone County White, Silver King, Improved Paymaster, Improved Southern White Snow Flake, Eureka, Bigg's Seven Eared, Hickory King, Wood's Gold Standard, Improved Golden Dent, Reid's Yellow Dent, Improved Leaming, Virginia Yellow Dent, Victory Yellow Dent, Virginia Ensilage, Pamunkey Ensilage, and Improved Yellow Creole. The writer selected the last-named variety in Louisiana during the winter of 1918–19.

The fertilizer tests have proved that it is absolutely essential to apply phosphate fertilizers in order to obtain a profitable yield of corn. The most economical results were obtained from those plats where a mixture consisting of equal parts of reverted and superphosphate had been applied at the rate of 500 pounds per acre.

Pigeon peas.—Probably the most important demonstration of the possibilities of a species relatively new to the islands as a field crop was that of the 15-acre field of pigeon peas first planted in March, 1917. Over a hundred other forage crops were tested, but the test with pigeon peas seemed to combine more good points with less unfavorable characteristics than any other crops which have been under observation. The fields were cropped from three to five times for seed and forage. (See Pl. X, figs. 1 and 2.) The product was cured as hay, which in turn was milled into meal and fed to all classes of live stock. As a result of this demonstration conducted by the station a neighboring rancher planted 350 acres. Part of this planting is now being harvested, milled in a well-equipped milling plant, and fed extensively to live stock on his ranch. It is estimated that probably 1,000 acres were planted in the Territory during the past two years, most plantings having been with seed bred especially by the Haiku demonstration and experiment farm for seed yield and other good qualities.

Alfalfa variety inoculation and fertilizer tests.—Previous to the year 1907, several unsuccessful attempts were made to establish stands of alfalfa. Even where the soil was well prepared, the young seedlings succumbed before attaining a height of more than 4 inches. Heavy manuring would have helped somewhat to overcome the difficulty, but owing to the limited quantity available this means of fertilizing was impracticable. In January, 1917, a combined variety test, inoculation, and fertilizer experiment was inaugurated with 4 strains of ordinary alfalfa, 2 strains of Peruvian, 2 strains of Grimm, 4 strains of Siberian, and 1 strain of an alfalfa received under the name of Liscomb. Plats that received the pure cultures (commercial) of tubercle organisms showed no appreciable improvement over the checks. One ton of hydrated lime per acre failed to show any benefit. Sulphate of potash, applied at the rate of 250 pounds per acre, gave no beneficial results. The plats which received a combined application of 100 pounds each of dried blood and nitrate of soda gave a very poor growth, little, if any, better than the check plats, and the plants finally died, as was the case with the checks. Stable manure when applied at the rate of 20 tons per acre resulted in a fair growth. The best results were obtained from the plats which received an application of 500 pounds of a mixture of equal parts of reverted phosphate and superphosphate. From the start the growth and development were excellent, a fact which indicates clearly that the only need of the soils in question was that of phosphate fertilizers.

The applications of phosphate fertilizers were repeated in January, 1918, and again in January, 1919. Notes on the relatives merits of the different strains and varieties were made in connection with plats

receiving applications of phosphate fertilizer. The alfalfas were seeded January 3, 1917, at the rate of 8 pounds of seed per acre in drills 18 inches apart. A mixture consisting of 500 pounds of equal parts of reverted and superphosphate was applied in the drills at the time of planting. The soil was raw guava upland from which one plant and two ratoon crops of pineapples had been harvested. This is one of the most unfavorable types of soil and its history has not been such as to warrant putting the soil in good condition. The varieties are arranged in the order of their apparent merit under the conditions, the best being placed first. The hairy type of the Peruvian alfalfa proved to be a vigorous upright grower, which recovered quickly after each cutting. The yield was 28 tons of green forage per annum from 12 cuttings. The smooth type of Peruvian alfalfa blooms from four to seven days later, and gives from 10 to 11 cuttings per annum, with a yield of green forage weighing about 25 tons. This variety, because of its smoothness, is usually more favorably regarded than the hairy type. The ordinary alfalfa was represented by four regional strains (Texas, California, Utah, and Idaho). These all did well under trial. Their leafage is more dense and in habit they are more spreading than the Peruvian type. They mature later, also. An average of eight cuttings, aggregating 20 tons of green forage per annum, was obtained. The variety received under the name of Liscomb did not differ materially from the common alfalfa. The two strains of Grimm alfalfa proved to be slow growing, somewhat stunted in habit, with small dense foliage. The yield was about 10 tons of green forage per annum. Under ordinary conditions in the islands this variety can not be recommended for hay; however, it may prove valuable for pasturage, especially under somewhat unfavorable conditions at the higher altitudes.

The Siberian alfalfas (Cossack, Orenburg, Cherno, and Semipalatinsk) were placed under test. While they are of too spreading a growth to be well adapted for hay-producing purposes they may prove valuable as pasturage where grown under unfavorable conditions of soil and moisture, as at the higher elevations where any palatable legume that will survive is to be favorably regarded. In the variety tests the yield ranged from 10 tons of green forage for the Cossack strain to less than 5 tons for the Semipalatinsk. The Turkestan variety made a poor showing and its culture is not recommended.

Experiments with potatoes.—This year marks the close of a four-year field experiment with potatoes. This experiment included comparative tests of numerous varieties, together with fertilizer and cultural experiments. The ordinary Kula (Maui) potatoes were formerly noted for their fine quality and fairly abundant supply in the Honolulu market. During recent years, however, both the quality and quantity have decreased to a marked degree. With a view to

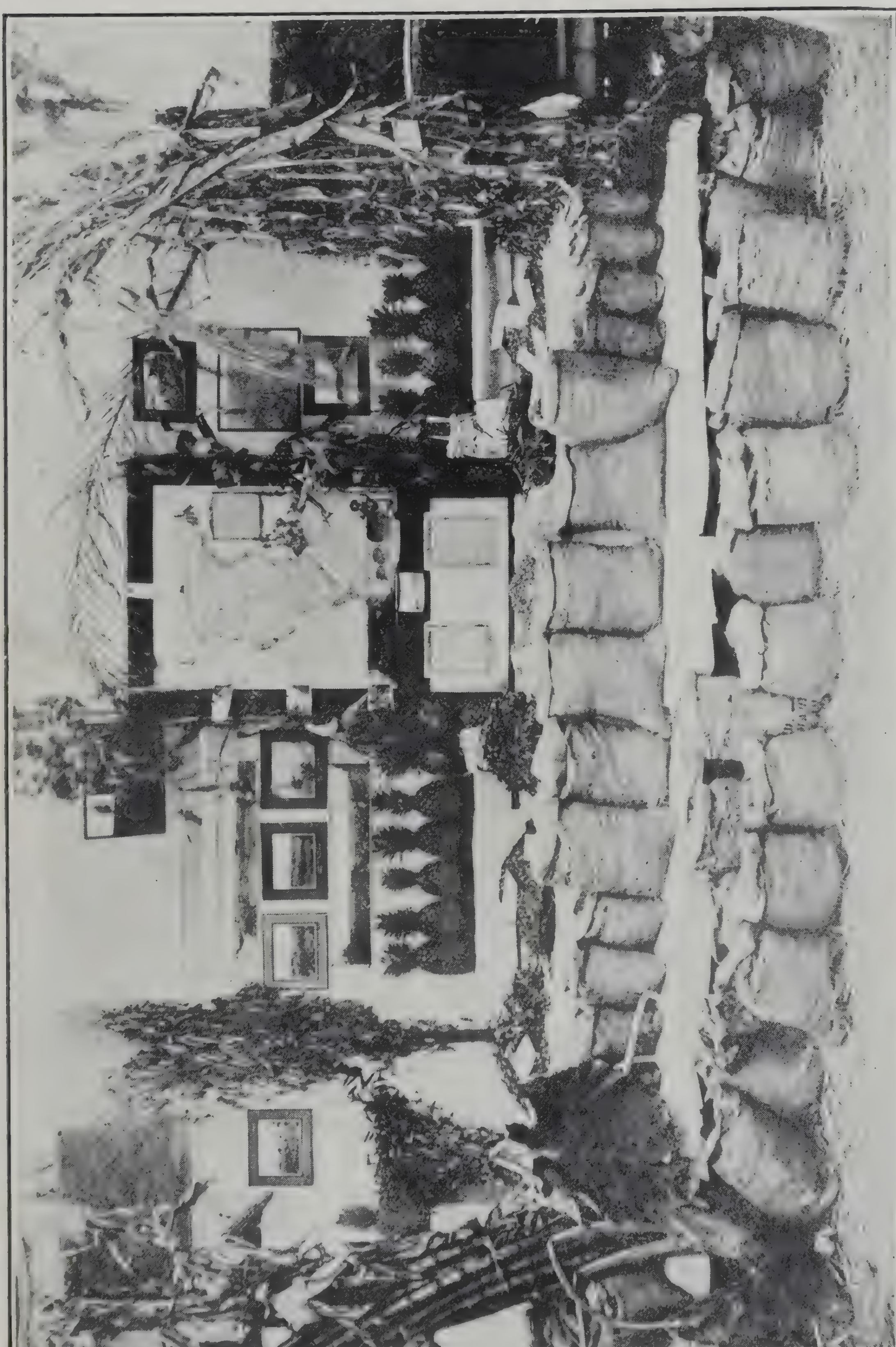

Exhibit of Products Grown in Cooperation With the Station, Showing the Possibilities of the Development of a 40-Acre Unit in 5 Years. Corn, Pineapples, Pigeon Peas, Taro, Sugar Cane, and Home-Grown Mixed Feeds for Live Stock.

FIG. 1.—PIGEON PEAS INTERCROPPED WITH CORN. PEAS CONTINUE TO OCCUPY LAND FOR 3 TO 5 YEARS.

FIG. 2.—HARVESTING AND CURING PIGEON PEAS ON HAY-CURING RACKS. PINEAPPLES IN FOREGROUND ROTATED WITH PIGEON PEAS.

rehabilitating the growing of this important food crop, restoring it to its former status, and, if possible increasing its importance, there was instituted in 1915 a rather comprehensive series of potato experiments. It was clearly shown that the best tilth possible should be provided on rather heavy soils. In order to maintain a fairly mellow condition of the soil throughout the growing season it was found necessary to incorporate in the soil a liberal amount of organic matter. The most practicable method of doing this proved to be that of turning under one or two good crops of velvet beans or cowpeas. About 25 tons of green matter per acre, when turned under, will ordinarily suffice to supply the requisite amount of organic matter in the soil.

It has been found from experience covering four successive seasons' plantings that to secure profitable yields it is essential to supplement the green manure with a liberal application of commercial fertilizer. A comparative test of the standard chemical fertilizers available in Hawaii showed conclusively that the phosphatic fertilizers are the controlling factor in maintaining a high degree of soil fertility. It was also found that potatoes respond to such fertilizers as readily as do corn, alfalfa, and other crops which, without the application of phosphate in some form, are practically failures. An application of 500 pounds of either superphosphate or reverted phosphate, placed in the hills at the time of planting, gave an increased yield of from 150 to 400 per cent over the untreated plats. Finely gound bone meal also gave satisfactory results.

In planting potatoes the best results were obtained where 2-ounce seed pieces, bearing at least two eyes, were used, the planting being made when the newly sprouted shoots were about one-quarter of an inch long. The potatoes were placed to sprout in single layers in subdued light where they were kept fairly cool by suitably controlled ventilation. Before planting, the seed was treated for scab, the whole tubers being immersed in a solution of formaldehyde, 1 pint to 30 gallons of water. It was also found that 4 ounces of corrosive sublimate to 30 gallons of water made an efficient dip. The seed was planted at 18-inch intervals in rows 30 inches apart, thus giving 11,616 hills per acre. About 1,500 pounds of seed per acre was used. In moderately dry seasons, plantings were made at from 4 to 5 inches in depth, but in moist seasons the seed was planted from 2½ to 3 inches deep.

One of the most critical problems in connection with the production of potatoes was that of eradicating the so-called blight and attacks from the recently noted mite and aphis. While these were responsible for considerable losses, methods have since been developed for safeguarding the crop by the use of Bordeaux-lime-sulphur spray

and nicotin preparations in adequate amounts. Such treatments add invariably to the cost of production, yet their very efficient results justify their use.

It is concluded that a lack of care in protecting the island's newly dug potatoes from sunshine is directly responsible for their poor keeping qualities. It is important that potatoes be placed in a cool dark storage as soon as they are dug. One of the varieties, when subjected to this treatment, kept in perfect condition for eight months. During the past two years the planting stock was grown from hill selected seed. The station's highest yielding variety gave an average yield of 1½ pounds per hill, but numerous hills yielded as high as 5 pounds of potatoes. It is regarded as fully established that carefully selected seed from individual hills will produce larger and more uniform crops than the general run of stock. The extension division has on hand a stock of selected seed potatoes of the New Era strain of Earliest of All, Producer, Snow, and White Rose. These are available for distribution to those planters who desire to test them, report on the results of the test, and, upon finding the varieties a superior kind, produce them in their own localities. The results of the potato variety test are shown in the table given below. No variety is included which for at least three seasons was not grown under field conditions. The range of yield in a variety during the different seasons has been as high as 40 per cent. The New Era Earliest of All yielded at the rate of 300 bushels to the acre, although the average yield was approximately 170 bushels per acre. During recent years yields as high as 170 bushels per acre under local conditions were very exceptional, even in the potato-growing districts of the island of Maui. In the Burbank varieties the low average yield was due to their late maturity and consequent susceptibility to blight and mites. These, on several occasions, have cut the crop short when otherwise an excellent yield would presumably have been obtained.

Results of potato variety tests at Haiku demonstration and experiment farm, showing approximate average yields, in pounds per acre, based on three or more crops.

Relative rank of variety.	Variety tested.	Approximate average yield per acre.	Relative rank of variety.	Variety tested.	Approximate average yield per acre.
		Pounds.			*Pounds.*
1	Earliest of All	10,200	13	Early Prizetaker	6,400
2	Producer	9,600	14	Gold Coin	6,200
3	Snow	8,350	15	Kula White	6,150
4	White Rose	8,100	16	Kula Flat	6,050
5	Bliss Triumph	7,700	17	Scotch Rose	6,000
6	Early Rose	7,600	18	Burbank, low top	5,950
7	Early Sunrise	7,400	19	Burbank, high top	5,400
8	Early Freeman	7,350	20	Burbank, Kula seed	4,650
9	American Wonder	7,250	21	Hamakua Hybrid (Kula, Kim strain).	4,000
10	Green Mountain	7,000			
11	Pride of Multnomah	6,500	22	Hamakua Hybrid (Yamata strain).	3,800
12	Netted Gem	6,450	23	Hamakua Hybrid (New Era strain	3,250

The division, basing its work on the results obtained in this variety test, is now using only the first five varieties listed, with the single exception of a select strain of low-top Burbank, which is to receive further trial. The earlier varieties, which usually escape the blight and mites, do decidedly better than the later-maturing sorts. After three years' effort, the selection work carried on to establish a variety immune to the blight has resulted in failure. It is thought that the best practice now available on Maui is that of growing early varieties best suited to the conditions and spraying them several times during the latter half of the growing season. These suggestions are made with special reference to the island of Maui, because there the conditions materially differ from those obtaining elsewhere in the Hawaiian Islands.

The cost per acre of growing a 100-bag (167 bushels) crop of potatoes at the Haiku demonstration and experiment farm was approximately $150. This includes rental of land, expense for tillage, seed, planting, harvesting, storage, etc. The crop, at present prices of $3.50 per 100 pounds, however, will be a profitable one if the yields produced by these best varieties can be maintained. When the yields fall to 50 bags (83 bushels) per acre, which is more than the average yield in the potato-growing districts of Maui, the profits are very small, although the cost of production is less there than in the Haiku section. A series of cooperative experiments in potato culture, the object of which is to demonstrate the most profitable methods of increasing the potato yield in those districts, is also in progress in the Makawao and Kula districts of Maui.

Pineapple experiments.—The pineapple experiments cover a tract of 10 acres; the first crop of this fruit was harvested at the close of the fiscal year. The experimental data, which require that each fruit be weighed as picked, necessitate as many as 2,500 individual weighings in the course of a single day's operations.

Tests with starch-yielding plants.—A considerable number of trial plantings were made with plants which, it is hoped, will ultimately become sources of commercial starch. These plantings included edible canna (*Canna edulis*), and several varieties of cassava, sweet potatoes, and taro. The observations, made in connection with a trip to the mainland during the year just closed, indicate the possibility of commercial production of starch on a large scale. Such an industry, once established in the islands, would constitute another of the diversified industries; and the residual product of these plants, after their starch had been extracted, would become an important source of economic carbohydrate stock feed.

REPORT OF THE GLENWOOD SUBSTATION.

By R. A. Goff.

The economical growing of food and feed crops continued to be the principal object of work done at the Glenwood substation during the past year. Purebred single-comb White Leghorn poultry was kept and eggs for hatching purposes were distributed throughout the island. While experiments with a number of promising crops were carried on, the work was mainly centered on potatoes, beans, cabbages, corn, and alfalfa. Unfavorable climatic conditions make it very difficult to produce many of those crops which are easily grown in other parts of the Territory. It was conclusively demonstrated that these five crops can be successfully grown in this district, and, in order to increase their yields, this station has tried to find better cultural methods.

The superintendent devoted much of his time to visiting homesteads and plantations in the Kau, Puna, Hilo, and Hamakua districts, assisting the farmer in every possible way by the distribution of seed and by imparting information, and in establishing fields of alfalfa.

The Glenwood substation, which was conducted principally with Territorial funds, received during the past year some assistance from the Federal Experiment Station in Honolulu, which paid the wages of two of its laborers.

IRISH POTATOES.

Three varieties of potatoes were planted, the Hamakua Hybrid (both red and white strains), the Portuguese Red, and Pride of Multnomah (an Oregon seed potato). The Multnomah, which consistently and repeatedly proved to be nonresistant to blight, has, therefore, been a failure in this district, where spraying is prevented by rains. The Hamakua Hybrid and Portuguese Red have made good yields. Marketable potatoes in yields of from 90 to 120 bags are usually obtained, and since they sell at from \$2.35 to \$3 per bag a good profit is usually realized from them. During extremely wet and cold years only one crop can be grown and the yields are lower, but in 1917 and in 1919 potatoes yielded well in this district.

In somewhat limited fertilizer tests with the Hamakua Hybrid, in which superphosphate and nitrate of soda, applied singly and in combination in varying amounts, and stable manure were compared, it was found that the use of equal amounts (250 pounds each per acre) of superphosphate and nitrate of soda was most economical.

SWEET POTATOES.

Twelve varieties of sweet potatoes, which were found growing in the Hilo and Puna districts, were planted. Of these five died and six grew slowly; the Laupuuwai, however, which made rapid growth and as yet has not been attacked by the leaf miner, is thought to be an excellent variety for this locality. The Madeira and New Era varieties produced well, but required over a year in which to mature.

MAUI RED BEANS.

The table below shows the results of a fertilizer experiment on eight plats, each 675 square feet, planted to Maui Red beans:

Results of fertilizer experiment with Maui Red beans

Plat No.	Fertilizer applied per acre.	Yield per acre.	Plat No.	Fertilizer applied per acre.	Yield per acre.
		Pounds.			*Pounds.*
1	Superphosphate, 500 pounds in 2 equal applications	1,400	4	Superphosphate, 250 pounds	1,195
2	Check, no fertilizer	780	5	Stable manure, 20 tons	1,800
3	Superphosphate, 500 pounds in 2 equal applications	1,235	6	do	1,975
			7	Check, no fertilizer	930
			8	Stable manure, 30 tons	2,030

It will be observed that stable manure gave the highest yields, but where a sufficient quantity can not be had for field planting, good yields may be obtained from the use of superphosphate alone.

DRY-LAND TARO.

Three varieties of taro, the Kuoho, Olaaoloa, and the Ala, were planted in February, 1919, and are doing better than any previously planted. The keiki, or sucker plants, are forming, and the crops should be ready to harvest by January, 1920. This is a somewhat longer growing season than is necessary at lower elevations, but a number of local growers have begun to plant taro where potatoes and cabbages do not thrive.

LICORICE ROOTS.

Roots planted in May, 1918, were a failure, since, after making a growth of three months, they died.

IMPROVED POHAS.

Records have been kept of the yields from the two plats of pohas which were planted in May, 1918. One plat contained the poha found growing wild in the woods; the other was planted to an improved giant variety obtained from Philadelphia. The native poha is perennial, and the pickings may be extended throughout the year.

The improved variety bears for a short season then dies. The native poha yielded 8 tons to the acre and the improved poha yielded $2\frac{1}{2}$ tons to the acre. The improved variety is a much larger fruit, and, while only 40 pounds of the native poha can be picked and prepared for market in a day, over 200 pounds of the improved variety can be easily prepared. Both varieties make excellent jam. Where cultivation of the improved variety is unnecessary this fruit should become a paying crop.

ALFALFA.

In the substation plats alfalfa yielded from 20 to 30 tons of green feed to the acre and can be cut 9 times a year. The fields are still developing and should, after another year, produce even better yields. At lower elevations in the north Hilo district, fields, planted under the supervision of the superintendent and cut 11 times in 12 months, are growing stronger after each cutting. Various methods of planting were tried, but the one found most suitable to local conditions of climate and weed growth is that of drilling the seeds in rows 2 feet apart. After 6 months' time the plants usually cover the ground and check weed growth, so that rather infrequent cultivation is required. When growing alfalfa it is very essential to have the fields in which it is to be planted as nearly weed-free as possible. The substation is keeping track of the costs of planting and bringing the crop to the first cutting stage, but as yet these data are not complete. Cooperative experiments in the planting of alfalfa were started in 12 localities on the east side of this island and so far are promising.

SWEET CLOVER.

Sweet clover is a slow-growing plant in this district, is not seriously attacked by insects, and produces nearly as well as alfalfa. It is an excellent feed for dairy cattle, grows on soils too poor for other legumes, and when turned under enriches the soil.

CORN.

Three varieties of corn, Waimea White, Guam, and Cuban Red, have given good yields, the Waimea White doing the best of the three. In the Glenwood district stable manure is a splendid fertilizer for fields planted to corn, and phosphate fertilizer gives almost as good results. In a comparative fertilizer test with Waimea White, stable manure gave a yield of 2,600 pounds of corn to the acre; phosphate, applied just before planting, at the rate of 400 pounds to the acre, gave a yield of 2,415 pounds of corn. Nitrate of soda and complete fertilizers, which are more expensive than phosphate, gave lower yields and can not be recommended. The average yield per acre of the three varieties was as follows: Waimea White, 2,415 pounds;

Guam, 1,650 pounds; and Cuban Red, 1,200 pounds. Guam corn doubtless would do as well as or even better than Waimea White at lower elevations, and Cuban Red, which has the advantage of being hardier and more resistant to pests, can be grown where other varieties do not give good yields.

SORGHUM.

Texas Blue Ribbon, Early Amber sugar cane, kafir, Egyptian wheat, and feterita were planted in order that a green feed for dairy cows might be secured. It was known that these would ratoon and in this way eliminate the necessity of replanting after each crop. Because of heavy rains it is often difficult to plant corn in the proper season, and if the sorghums can be made to ratoon well, they will prove of inestimable value to local dairymen. In Hawaii all of these varieties mature seed which probably would become a source of poultry feed were some method to be found which would prevent birds from eating the maturing grain. The crop, secured from planting seed, averaged 22 tons of green feed to the acre, but the ratoon crops so far have been stunted and have not been used for fodder because of the possibility of their poisoning the cattle. As the sorghums continue to ratoon after each cutting, different fertilizers are being applied in an effort to secure a quick-growing, heavy second growth.

EDIBLE CANNA.

The edible canna which was introduced as a substitute for potatoes is now more largely used as a hog feed. At this elevation it produced 7 tons of roots to the acre with a nine months' growing season, but matures more quickly at lower levels. When well fertilized, the tops grow to a height of 8 or 9 feet; these tops, after being cut in 6-inch lengths, are fed by local growers to hogs. The roots as well as the tops are relished and furnish a large part of the ration; the latter, when mixed with 2 pounds of soured rice bran, cause the hogs to steadily increase in weight. Small fields of canna are kept growing at the substation and cuttings are distributed among homesteaders.

CASSAVA.

Cassava, from which tapioca is made, makes a rapid growth in the Puna district of this island. Cuttings were secured from that place and planted at the substation in the late autumn of 1917. It failed, however, to reach the size of plants 5 months old at the lower elevation. Waialua White and Trinidad varieties were also planted and are maturing slowly. A very good grade of edible starch can be made by grating the roots, and, after mixing them with water, straining them through cheesecloth. The value of these roots as a hog feed

is being recognized by many growers to whom cuttings were distributed.

PIGEON PEAS.

Pigeon-pea bushes grow to a height of 5 and 6 feet in the substation plats, and, although they do not mature seed, their younger branches, when cut off and ground, furnish a palatable feed for dairy cows. Since they are legumes, they have the added advantage of enriching the soil, especially when turned under as a green manure crop. Seed which was distributed to farmers in the vicinity of Hilo has developed into plants which are now bearing seed. The pigeon-pea crop is highly prized by those who have raised it.

GRASSES.

Demonstration plats of Kentucky blue, awnless brome, redtop, timothy, orchard, crested dogstail, Italian rye, and meadow fescue grass, planted in 1917, continued to grow well throughout the year. Originally planted in rows 3 feet apart, the redtop and Kentucky blue grass have spread until they now cover the ground and form a heavy mat; this feature makes the grasses valuable additions to the pastures of this district. Less than an acre of *Paspalum dilatatum*, or Australian water-grass, which was planted in 1916 from roots set in 2½-foot rows, furnishes all of the grazing needed for one dairy animal, since it has spread until the ground is almost entirely covered. Six acres of the native or wild grass is necessary to supply grazing land for one animal, so that Paspalum is easily worth five or six times as much as the grass found in the majority of local pastures. This station secured seed of these grasses for local dairymen who desired to improve their pastures. Twelve varieties of grasses and leguminous plants from Florida were planted in the field and in flat boxes, but failed to germinate.

POULTRY.

Purebred single-comb White Leghorn poultry has been kept, and eggs for hatching were distributed throughout the island at a nominal price. The entire flock netted a return of 26 cents per bird per month above cost of feed. At the same time, the flock supplied the hatching eggs used at the station and paid for the feed used by over 300 growing chicks. The hens of the entire flock average 12 eggs per month. The feed cost of each hen is 30 cents per month; the return above feed cost, when the eggs are sold on the market, is over 40 cents per bird. It has cost the station 85 cents on the average to bring a pullet to the age of 3 months, exclusive of the labor required, and about $2 to care for it until the time of laying. Poultry raising should become profitable in the Territory where small flocks are kept as a side line or in larger flocks of about 500.

COOPERATIVE EXPERIMENTS.

After demonstrating in experiment plats that phosphate fertilizers as well as complete fertilizers return large yields of potatoes per acre, arrangements were made with a Glenwood farmer to carry on a cooperative fertilizer experiment on his land. An acre was divided into eight equal plats to one of which a complete fertilizer was applied by the farmer at his usual rate of application. Another plat was reserved as a check plat where no fertilizer was applied; and in the other six, reverted and superphosphate were applied by the substation at the rate of 250, 500, and 1,000 pounds per acre. A second application of 150 pounds per acre was given to the plats which had received 250 pounds. The potato rows were about 40 inches apart and the fertilizer was applied in the rows and not scattered broadcast. At harvest time it was found that all the fertilized plats returned a 30 per cent larger yield than the check, and that the plats in which 400 pounds of phosphate had been used gave as large yields as the one in which the more expensive complete fertilizer had been used. Practically all of the potatoes planted in Glenwood this year have been fertilized with phosphate at a considerable saving to the planters as a result of the experiment, and all indications point to a larger yield than in previous years. The superintendent has ordered all the phosphate for the local growers, and will continue to do so until satisfactory arrangement for their purchase can be made with local dealers. On various farms demonstrations were also made of the use of poisons for cutworms, cabbage worms, potato blight, and sweet-potato leaf miner. Assistance was given to homesteaders in the purchase of reliable seed and poison for the various pests.

SCHOOL-GARDEN CONTESTS.

The superintendent acted as judge in the Star-Bulletin school-garden contest in the districts of Puna and Kau and in the final judging in the Kona district. He also served as judge in the Hilo Board of Trade home-garden contest.

BOYS' WORKING RESERVE.

The superintendent for four months acted as county director of the Boys' Working Reserve work on this island and for nine months had charge of the work on the east side. A trip was made around the island of Hawaii with G. A. Young, the executive secretary of the reserve in the Territory; a motion-picture machine was used to give exhibitions, and in each of the districts a practical talk was given.

HAWAII AGRICULTURAL EXPERIMENT STATION
HONOLULU, HAWAII

Under the supervision of the
UNITED STATES DEPARTMENT OF AGRICULTURE

REPORT OF THE HAWAII AGRICULTURAL EXPERIMENT STATION

1922

Issued July, 1924

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1924

HAWAII AGRICULTURAL EXPERIMENT STATION, HONOLULU.

[Under the supervision of the Office of Experiment Stations, United States Department of Agriculture.]

E. W. ALLEN, *Chief, Office of Experiment Stations.*
WALTER H. EVANS, *Chief, Division of Insular Stations, Office of Experiment Stations.*

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[1] Resigned Nov. 1, 1921. [2] Appointed on part-time basis.

HAWAII AGRICULTURAL EXPERIMENT STATION
HONOLULU, HAWAII

Under the supervision of the

UNITED STATES DEPARTMENT OF AGRICULTURE

Washington, D. C. July 11, 1924

REPORT OF THE HAWAII AGRICULTURAL EXPERIMENT STATION, 1922.

CONTENTS.

SUMMARY OF INVESTIGATIONS.

By J. M. Westgate, *Agronomist in Charge.*

During the fiscal year 1922 the station continued to emphasize the necessity of furthering the diversified agricultural industries of the islands by promoting the production of many new and improved forage crops, fruits, and vegetables and by working out rational cropping systems suitable to sugar cane and pineapple growing.

Introducing such new plants as are believed to be of economic value and improving many of the useful fruits now under cultivation in the Territory by breeding and selection work has constituted a major project of the horticultural division. The best of these will be propagated and distributed to growers throughout the Territory. During the year, 232 different varieties were received and 22,100 plants of improved and promising strains distributed.

Agronomic investigations were carried on with root, green-manuring, grain, and forage crops, and also with aquatic crops of economic importance and oriental origin. To meet the needs of those combining poultry raising with vegetable gardening, the agronomist devoted part of his time to poultry work, introducing breeding stock of high egg-producing capacity, and conducting caponizing and culling demonstrations.

In the chemical division investigations were conducted to determine the most profitable utilization of surplus fruits which are prevented by quarantine regulations from being exported. The dehydration of certain fruits and vegetables and the making of jams, jellies, and preserves promises to become of commercial importance.

The resignation of the superintendent of extension on November 1, 1921, necessitated considerable readjustment of the various activities of the station and the assignment of certain phases of the department to other workers, pending the filling of the vacancy.

Many of the projects of the Haiku substation were brought to a satisfactory close and others were transferred to the Haleakala substation and demonstration farm for continuation. A few of the projects are being carried on in connection with the station by the new manager of the farm on which the Haiku substation was located.

The extension agent for the Island of Hawaii devoted the major part of his time to orchard work and to the improvement of pastures on the various cattle ranches. During the year he traveled 11,200 miles, mostly by automobile, and visited 1,500 farmers, in addition to distributing bulletins, vegetable and fruit seed, young nursery stock, and cuttings and suckers to homesteaders, ranchmen, and plantation managers. Much assistance was given in ordering varieties of seed, in selecting seed in the field, and in applying the right amount of fertilizer to the different soils of the various localities.

Home demonstration work was continued on practically the same scale as last year, the home economics demonstrator again working part time as collaborator and operating through various local organizations, assuring large interested audiences.

The station made a representative exhibit of various phases of its work at the fourth annual Maui County Agricultural Fair, which was held from October 15 to 23, inclusive, and several members of the staff acted as judges on a number of the important fair committees.

REPORT OF THE HORTICULTURAL DIVISION.

By W. T. Pope.

MISCELLANEOUS FRUIT INVESTIGATIONS.

BANANAS.

Renewed activity in banana growing is very apparent, and in many places small plantations are starting. No large corporations have as yet entered the industry. Approximately 18,000 bunches per month were shipped to the markets of the mainland during the year, and prices fluctuated considerably, the net wholesale price per pound f. o. b. Honolulu wharf ranging from $0.027 in July and August, to $0.043 in January and February. The price of offshoots of the Chinese banana ranged from $15 to $20 per hundred, and Bluefields, which are rarely available, were even higher. Brazilian and Ice Cream sold for $5 to $10 per hundred.

The station is growing 26 different varieties of bananas in a sheltered valley at the Tantalus substation and plans to select promising varieties from this collection for determination as to their commercial possibilities. Kona Maiamaoli, an excellent banana which has been grown for generations in the Kona district is thought to have a great commercial future. (Pl. I, fig. 1, and Pl. II, fig. 1.) The Chinese variety is considered most desirable of all for planting in the lower elevations and in gardens, being a low-growing plant which produces large fruit early in the season. Offshoots from a small planting at the central station were distributed during the year to school and home gardens. Bluefields is a good shipper, but the

plant is tall growing and should be planted in localities that are relatively free from strong winds. Brazilian and Ice Cream withstand considerable wind, but are grown for local consumption only. Popoulu Kaio is an excellent native variety. (Pl. I, fig. 2, and Pl. II, fig. 2.) The native varieties, which are classed chiefly as cooking bananas, are raised for local use only.

PAPAYAS.

The papaya is more in demand than ever in Hawaii and brings such high prices on the market that most dealers retail their fruit by the pound.

The papaya investigations, which were begun by the station about two years ago, are already showing interesting results. Seedlings of the Solo variety, which is composed of several strains each differing in shape of fruit, have just come into bearing, producing fruit of superior form and quality to that of the parent. (Pls. III and IV.) The trees conform to the ideal in that they have short, stout trunks and begin early to bear an abundance of fruit. In many instances, 11-months old trees support a weight of 40 to 70 pounds.

It is quite evident that papayas of very high quality can be produced by proper methods and that the nature of the flesh of the fruit changed by direct cross-pollination, just as is the case with the seed. It is hoped that the monœcious type can be developed to such an extent that choice characters will not be frequently changed by cross-pollination.

Grafting methods were not satisfactory to any great extent in the production of standard fruit, but when lateral branches were planted as cuttings the fruits produced equaled those of the parent tree in quality. The terminal growth may be removed from 2-year old trees which bear their fruit too high to permit of convenient picking. This will cause lateral buds to sprout from some of the leaf scars along the trunk. When these laterals attain a length of 1½ or 2 feet they can be removed and set 8 or 10 inches deep in coarse gravelly soil. Given careful attention, they will soon root and develop as new trees, producing fruit of excellent quality. Some trees produce only few laterals, while others develop 25 or even 50.

Papayas of very fine quality may be produced from selected seed for general purposes provided they are given good culture. The seedlings should be planted 8 feet apart each way in rows in rich soil with good drainage. The soil about the plants should be enriched with thoroughly decomposed barnyard manure at the time of planting, and the young trees given clean culture and plenty of water if a large yield of well-flavored fruit is to be expected.

During the year seed of the Dapitan papaya germinated, and the young seedlings were set in a trial plat. This variety was received from the Philippine Islands.

CITRUS FRUIT.

The citrus orchard, which now contains 160 trees representing 35 different varieties, is located on the southeastern slope of Punchbowl Mountain where the soil is of tufa lava origin. This orchard was fertilized with barnyard manure and given thorough cultivation

during the spring, summer, and fall months. Early in November it was sown with mungo beans (*Phaseolus mungo*), 150 pounds of seed being broadcasted per acre, and in April the cover crop was turned under. The treatment greatly improved the soil, and the Kusaie lime and several varieties of orange and lemon trees bore heavy crops of fruit as a result.

After making an extended survey of the orange trees growing in the district of Kona, the horticulturist has succeeded in obtaining bud wood from what is thought to be the best Hawaiian (Polynesian) orange tree for budding on seedling stocks of sour orange and rough lemon trees growing at the central station. The tree is vigorous and prolific and produces large, smooth-skinned, sweet, juicy fruit containing few seeds. Several consignments of the bud wood have been propagated for distribution. Cooperative experiments are being carried on with W. D. Ackerman and W. H. Greenwell, who have set out an acre of these selected budded trees in Kona.

About 50 sweet shaddock trees have been propagated from a tree producing fruit of very fine quality. The original tree is owned by Mr. and Mrs. Henry A. Gehring, Honolulu, who kindly permitted the removal of graftwood that this choice fruit might be made available to others.

AVOCADOS.

Of the 40 budded varieties of avocado trees in the orchard at the Tantalus substation, 14 are of the Popenoe Guatemalan collection. These trees are growing without irrigation at an elevation of 1,000 feet. Some are now past their third year, six have blossomed, and two are setting fruit. Bud wood of the varieties Northrup, Taft, Solano, Puebla, Harmon, Fuerte, and Trapp, which are in common cultivation in California, has been received and successfully propagated. Fully 85 varieties are now under trial at the station, and 5 cooperative experiments with private owners are being carried on.

An effort is being made to group varieties fruiting at different seasons, so that the fruit may be in season throughout the year instead of being confined practically to the summer months. In the Kona district some trees of the West Indian type ripen their fruit during the winter months, while on Oahu the trees usually ripen their fruit in the summer. Among those producing fruit in the fall, winter, and spring are Beardslee (Ables), Macdonald (Pl. V, fig. 1), Nutmeg, Kalua, Wilder, Kinau, and the Case avocado (Pl. VI, fig. 1), all of which have considerable local reputation for quality.

During the year the station propagated over 800 seedlings for use as rootstocks in further experimental propagation work.

One of the important observations noted in connection with avocado growing is the frequency with which seedlings, the progeny of good varieties, develop fruit of good quality. In many instances the fruit is superior to that of the parent.

MANGOES.

Ninety trees of various varieties of mango are under trial, the most promising of which are being propagated for distribution. The least desirable trees have been removed to give space to the remainder and to permit of the cultivation of the orchard. Pruning and culti-

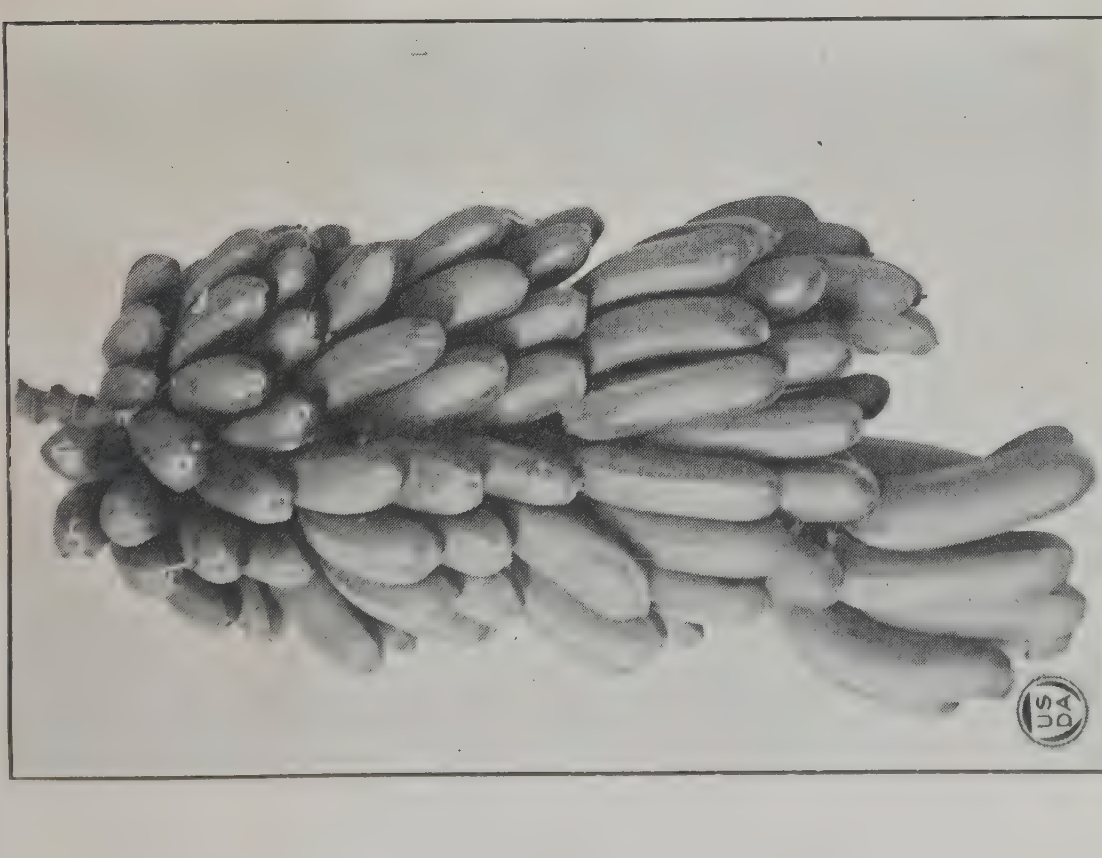


FIG. 1.—BANANA, NATIVE VARIETY KONA MAIA-MAOLI. ONE OF THE BEST HAWAIIAN COOKING BANANAS.

FIG. 2.—BANANA, NATIVE VARIETY POPOULU KAIO. BUNCH MEDIUM SIZE; AVERAGE WEIGHT, 30 POUNDS. USED AS FRESH FRUIT OR COOKED.

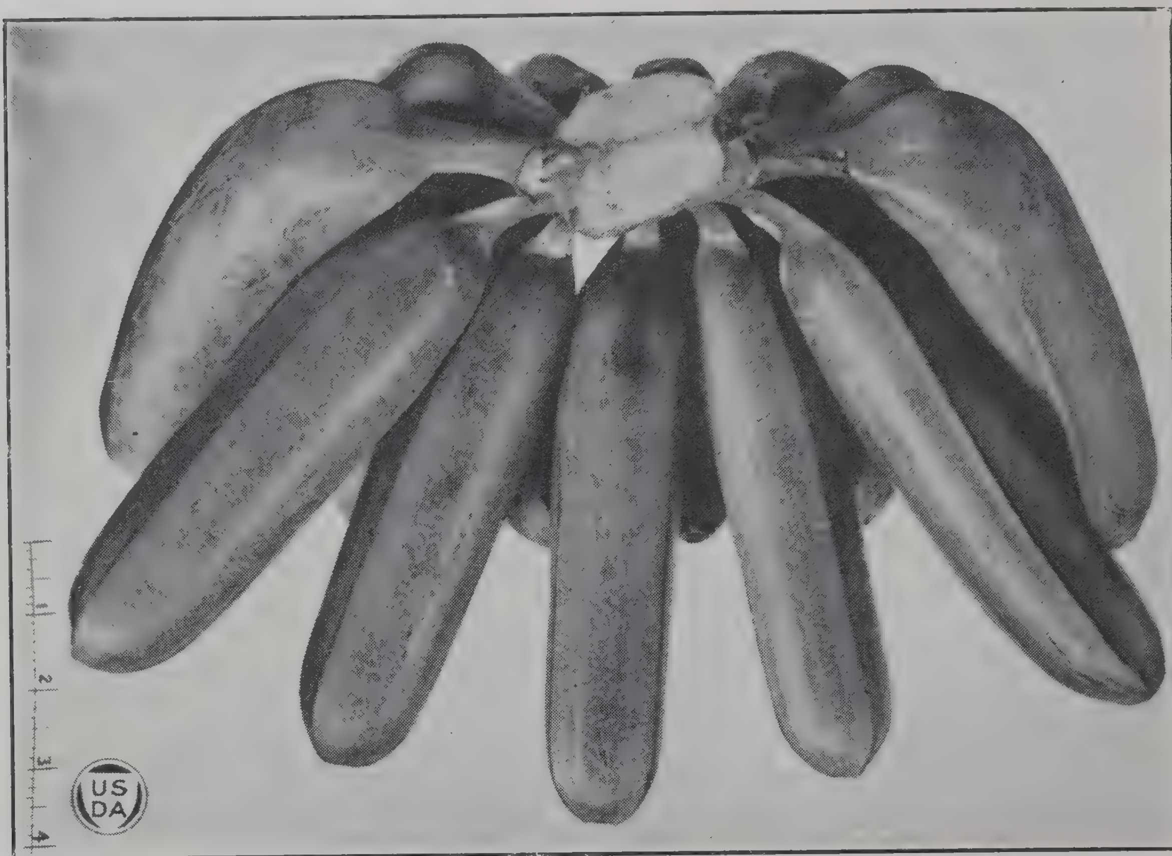


FIG. I.—HAND OF KONA MAIAMAOLI BANANAS.

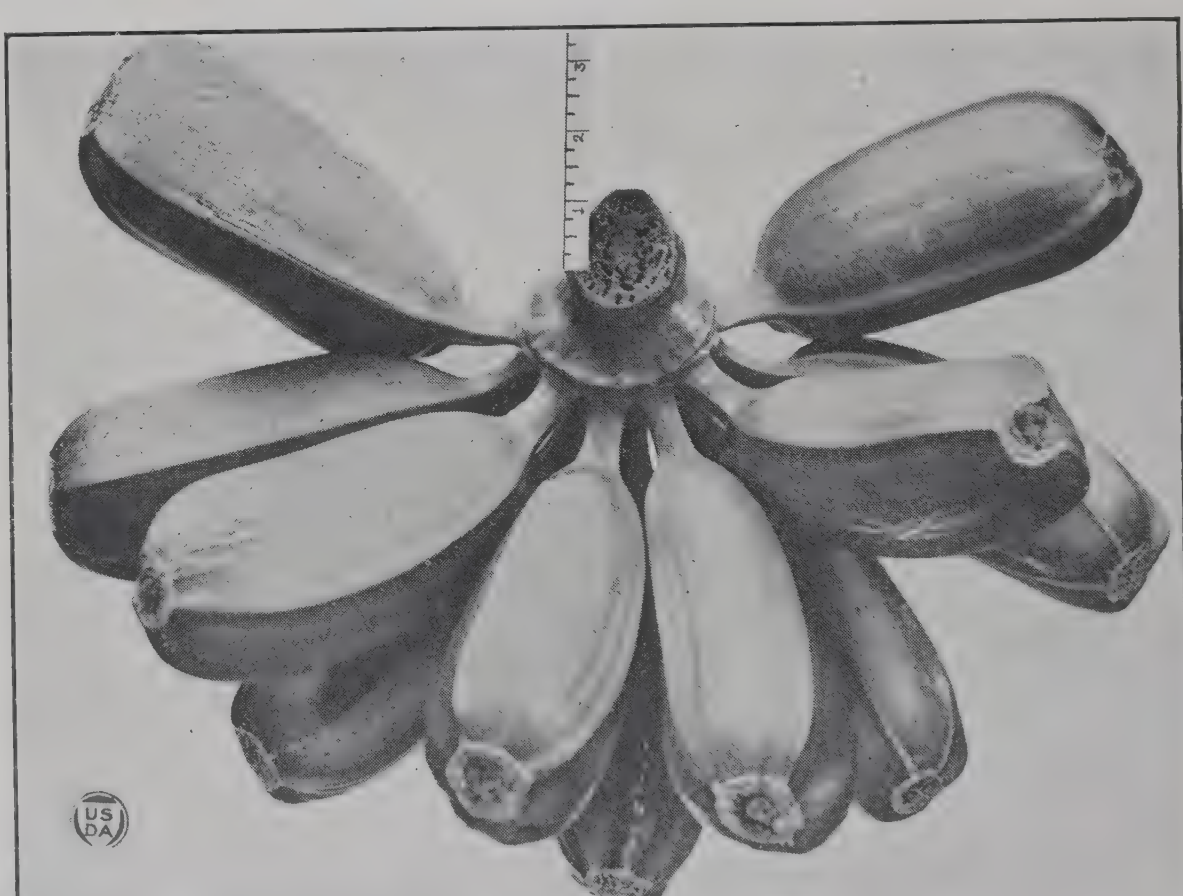


FIG. 2.—HAND OF POPOULU KAIO BANANAS.

FIG. 2.—PAPAYA NO. 4618. LONG TYPE.

FIG. 1.—PAPAYA NO. 4610. ROUND TYPE.

FIG. 1.—PAPAYA NO. 4610. FRUIT WEIGHS 4 POUNDS. COLOR, BRIGHT YELLOW.

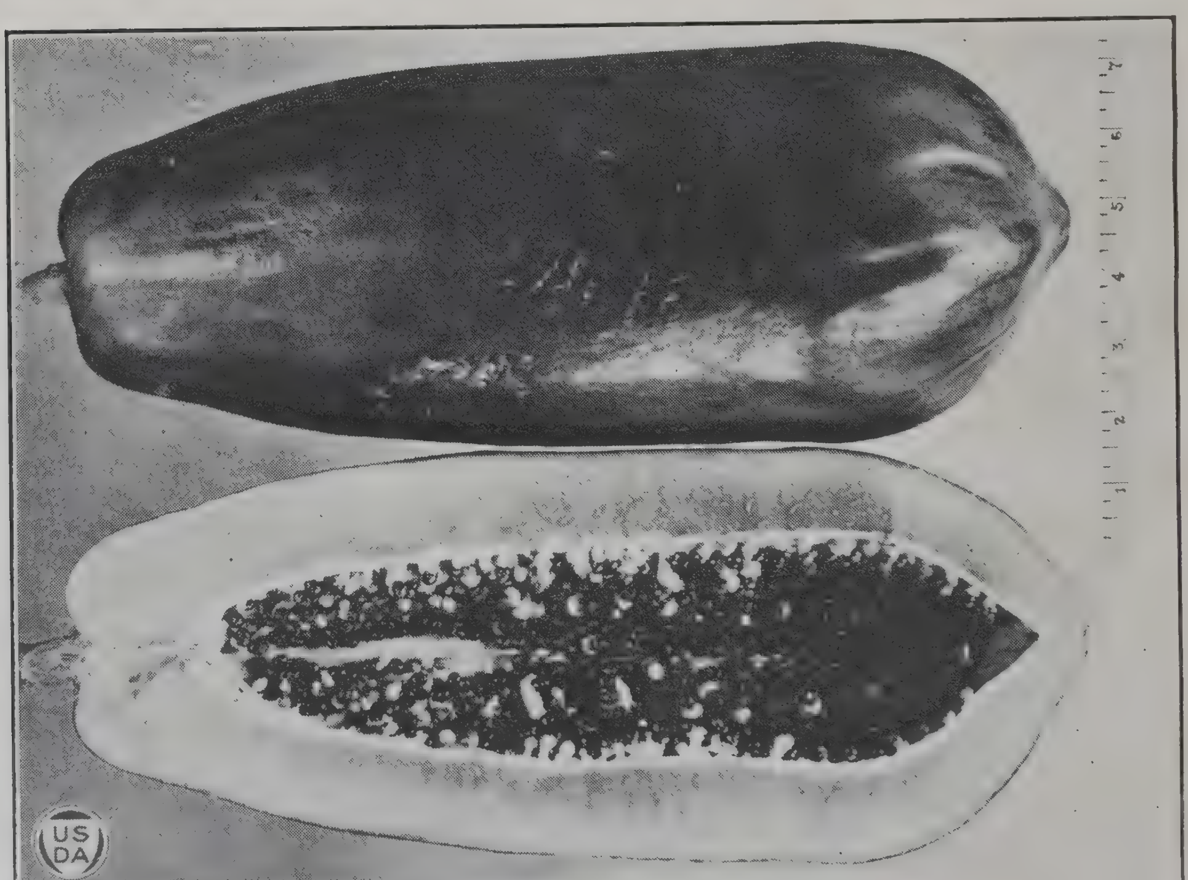


FIG. 2.—PAPAYA NO. 4618. FRUIT WEIGHS 6½ POUNDS. COLOR, YELLOW.

vation have helped to improve both yield and quality of the fruit and to reduce the ravages wrought by the mango weevil (*Cryptorhynchus mangiferœ*. Experiments show that the Pirie can be propagated by the bark-graft method, several hundred 1-year old seedlings having been successfully grafted with scions of this variety. Fourteen hundred seedling mangoes are being grown for grafting and budding to a number of good varieties which as yet are hardly known in the Territory. Local varieties springing from West Indian stock seem to do better and to be more prolific than Indian varieties, many of which are shy bearers and often fail to produce for several years in succession.

Victoria.—Among the seedlings developed from seed introduced into the islands from the West Indies during the 80's was a mango known as No. 9. Seed of this tree was planted on the date of the diamond jubilee of the late Queen Victoria of England, and the resulting tree was called Victoria. (Pl. VI, fig 2.) The tree is very prolific, producing sometimes as many as three crops a year. The fruits are usually produced singly on individual stems and differ in color from any other variety of mango growing in Hawaii, being red from the time they set and becoming brilliant scarlet on ripening. Like some other mangoes, the Victoria reproduces its quality of fruit fairly true to type on seedling trees. This variety may be propagated by grafting.

The fruit is of medium size, weighing about 9 ounces. Form, oblong, slightly S shaped, and at stem end somewhat necked; apex, broadly rounded with curve ending in a small blunt beak sometimes containing small hole-like depressions; color when ripe, brilliant vermilion shaded over yellow background, especially at the apex; surface, marked with small yellow dots, which become overcast where red is deepest; shoulder of fruit has delicate powdery bloom; skin, of medium thickness and peels off well; aroma, pleasant; ripe flesh, deep rich, yellow color and good texture; juice, sweet, acid, and of flavor of Pirie mango; seed, small, weighing three-quarters ounce; marketing qualities ranking among best varieties in Hawaii.

Wootten.—The Wootten is one of half a dozen trees which were inarched from the original tree growing in the yard of H. Wootten, on Makiki Street, Honolulu. Even before it is fully ripe, this variety has a beautiful coloring which is a very desirable marketing feature. In moderate temperatures the ripe fruit will remain in good condition for two weeks.

The fruit is medium to large; form, roundish, slightly flattened on the sides (no apex point evident); weight, about 10 ounces; color when ripe, a shade between orange yellow and yellow orange with tinges of pink and red at the stem end and pale yellow dots scattered over the surface; skin, medium thin, tough, and with fair peeling qualities; aroma, very pleasant; flesh, rich apricot yellow of very good texture; flavor, excellent; juice, sweet, acid; seed, medium to small for size of fruit.

Kalihi.—This hybrid is thought to be the result of a cross between a West Indian variety known as No. 5 and some other West Indian mango which grew in the Government nursery grounds on King Street, Honolulu. The trees are vigorous and prolific and produce fruit of fine quality when given cultivation.

The fruit is of medium size (Pl. V, fig. 2), weighing 11 ounces; form, oval with broad stem-end, which is depressed like that of the apple; apex end, broad, terminating in two rounded points, one of which is more prominent than the other; when ripe, the color is golden apricot splashed over the shoulders with blood-red spots and dotted over the whole surface with light yellow; skin, medium thickness, rather tough, peels off well; aroma, pleasant; ripe flesh, deep, rich yellow, of good texture; juice, sweet with subacid flavor; seed, medium to small, weighing three-fourths ounce. The fruit has good keeping qualities.

GRAPES.

The past year was favorable for the production of grapes, and the locally-grown fruit appeared constantly on the markets. The station is attempting to supplement the Isabella variety, the leading grape of Hawaii, with eight other varieties which are known to possess desirable qualities. These will be grafted on Isabella rootstocks for immediate production and cross-pollinated in an effort to secure improved table grapes suitable to island conditions. A number of vines of the Isabella variety have already fruited lightly. The tropical species known as *Vitis tiliæfolia* (S. P. I. No. 44060), introduced last year from the Bureau of Plant Industry, United States Department of Agriculture, has made good growth and is thought to have a future in connection with Hawaiian grape growing. Muscadine grapes, popular in the Southern States, are other introductions which are likely to become established.

The vineyard has been kept well cultivated and given irrigation when necessary, and the vines have been supported on a trellis of the Munson type. Sprayings with arsenate of lead have kept the Japanese beetle (*Adoretus umbrosus*) under control.

STRAWBERRIES.

New varieties of strawberries are being tested, and the growing of this fruit under screen in the home garden is being encouraged. It is thought that by inclosing a small strawberry bed in a specially constructed frame built after the manner of a hotbed and covered with heavy galvanized screening No. 26 (eight meshes to the inch) choice fruits can be grown under high culture without danger of its being destroyed by the Japanese beetle (*Adoretus umbrosus*). At the station an experimental frame of redwood 6 feet wide, 32 feet long, and 18 inches deep has been set in the soil to a depth of about 9 inches. The screens have been tacked to sashlike frames 4 by 6 feet and made to fit into the top of the frame resting on cleats. These are kept over the plants only at night, as the Japanese beetle is strictly nocturnal in flight and feeding. Inside the frame the varieties "New Carolina," Brandywine, and Progressive have been set in rows 1 foot apart in a bed of clean fresh soil with which well decomposed barnyard manure has been incorporated. Where the fruit is of such soft and quick growth and so hidden in the foliage as is the strawberry, a poisonous spray can not be safely used, and it is thought that the method outlined above will enable one to grow enough choice strawberries in the garden for family use at a reasonable cost.

TOMATOES.

The experiments in tomato improvement, which have for their object the development of varieties resisting attacks of the melon fly (*Bactrocera cucurbitæ*) and the Mediterranean fruit fly (*Ceratitis capitata*) and bearing fruit of increased size and improved quality, were continued.

The cross secured by hybridizing Earliana with the small, native tomato resulted in the production of a large tomato having fixed characters. It has the shape and toughness of skin of the wild tomato and some of the size and quality of Earliana. Seedlings of nearly 200 other variety hybrids, obtained in the same way, are being developed in order that it may be learned if they will continue to be reproduced true from seed.

Of a large number of interesting hybrids raised during the year, 53 have been selected for determination as to their ability to transmit their desirable qualities.

The results of the experiment are proving satisfactory, yields in general being large, and only few of the variety hybrids being susceptible to fly attacks.

OTHER FRUITS.

Root cuttings of the seedless breadfruit (*Artocarpus inscisa*) were propagated from surface roots in the fall. Six-inch cuttings which were laid horizontally in coral sand several inches below the surface made the best growth.

In September, 1921, a fine collection of seeds of the longan (*Euphoria longana*) was received from the Department of Productive Industries, Formosa. Eighty healthy seedlings have been grown from this seed, although it was in a sprouting condition when it arrived.

One thrifty mangosteen tree (*Garcinia mangostana*), sent from the United States Department of Agriculture, is growing at the station. Twenty-four trees of this species were received from Java during the year, but all were dead on arrival. Efforts will be continued to establish this valuable species in the Territory.

Root cuttings of a number of varieties of fig (*Ficus carica*) have been distributed, and two new varieties, a small, yellow fruited sort, and the Kadota, a white fig from California, are being propagated.

Seeds of the Pejubaye palm (*Guilielma utilis*) from Central America have been placed in sand for germination. The flesh about the seeds is the edible portion and is said to be of high food value. It is hoped that this useful tree can be established in the islands.

Seedlings have been grown from a number of seeds of the tree tomato (*Cyphomandra betacea*) which were received in the autumn of 1921.

Strawberry guavas (*Psidium cattleianum*) of an improved strain are being grown in the station orchard, and many young trees are being propagated for distribution.

NUTS.

COCONUTS.

Although all the coconut trees in the Territory are of the species *Cocos nucifera*, they have fixed characters which are peculiar to the

group of Pacific Islands whence it came. These characters reproduce even when the nuts are grown in Hawaii.

Tests of three materials were again made to determine the quickest and best way to secure germination of coconuts. Nuts were buried in rice hulls in the first test, in coarse black sand in the second test, and in coral beach sand in the third test, being placed in each case in pits 18 inches deep. Some nuts in each pit were buried whole, while others, from which a portion of the outer hull was removed at the base, were set with cut ends up just below the surface. Those set in rice hulls with cut ends up germinated best, sending up shoots in two and three months.

MACADAMIA.

Only a small crop of Macadamia nuts was obtained from the trees growing at the Tantalus substation. A number of these germinated, however, 50 young trees being set out at the substation and several hundred distributed throughout the Territory. The Macadamia will grow in the warmer localities near sea level, but it thrives better and makes more rapid growth in the cooler places.

PILI.

Several hundred Pili nuts (*Canarium ovatum*) were received from J. E. Higgins, of the College of Agriculture, Philippine Islands, during the year. Various tests were made to determine the best way to secure germination, but in each instance the percentage of germination was low.

PISTACHIO.

The pistachio is being propagated in the hope of getting it established in the Territory. Budding and grafting experiments will be undertaken as soon as the seedlings (*Pistacia vera* and *P. chinensis*) reach sufficient size. With the great variations of climate existing in the Hawaiian Islands it is thought that some locality can be found where this valuable nut will thrive.

REPORT OF THE AGRONOMY DIVISION.

By H. L. Chung.

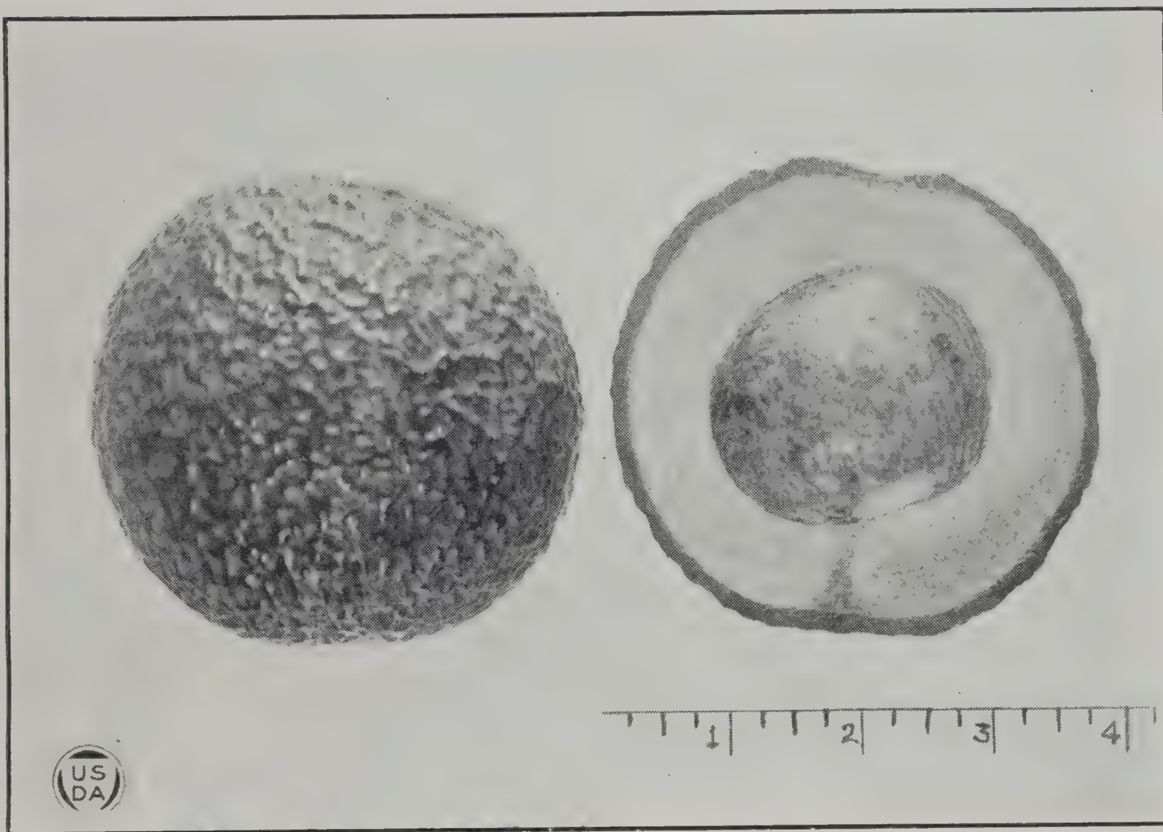
ROOT CROPS.

CASSAVA.

Twenty-two varieties of cassava (*Manihot utilissima*) were grown in a light clay soil to determine their yielding values. The crop was harvested June 7, 1922, after a growing period of 15½ months. The four outstanding varieties for yield were São Pedro Preto, Tapicura, French No. 3, and Basioroa, which produced at the rate of 19.10, 13.23, 12.76, and 11.59 tons, respectively, per acre.

MANGEL WURZELS.

In December, 1921, a test of four varieties of mangel wurzels was undertaken to determine their yield when grown on a medium-clay



Macdonald

FIG. 1.—~~BEARDSLEE~~ AVOCADO. HARD-SHELLED FRUIT OF EXCELLENT QUALITY.

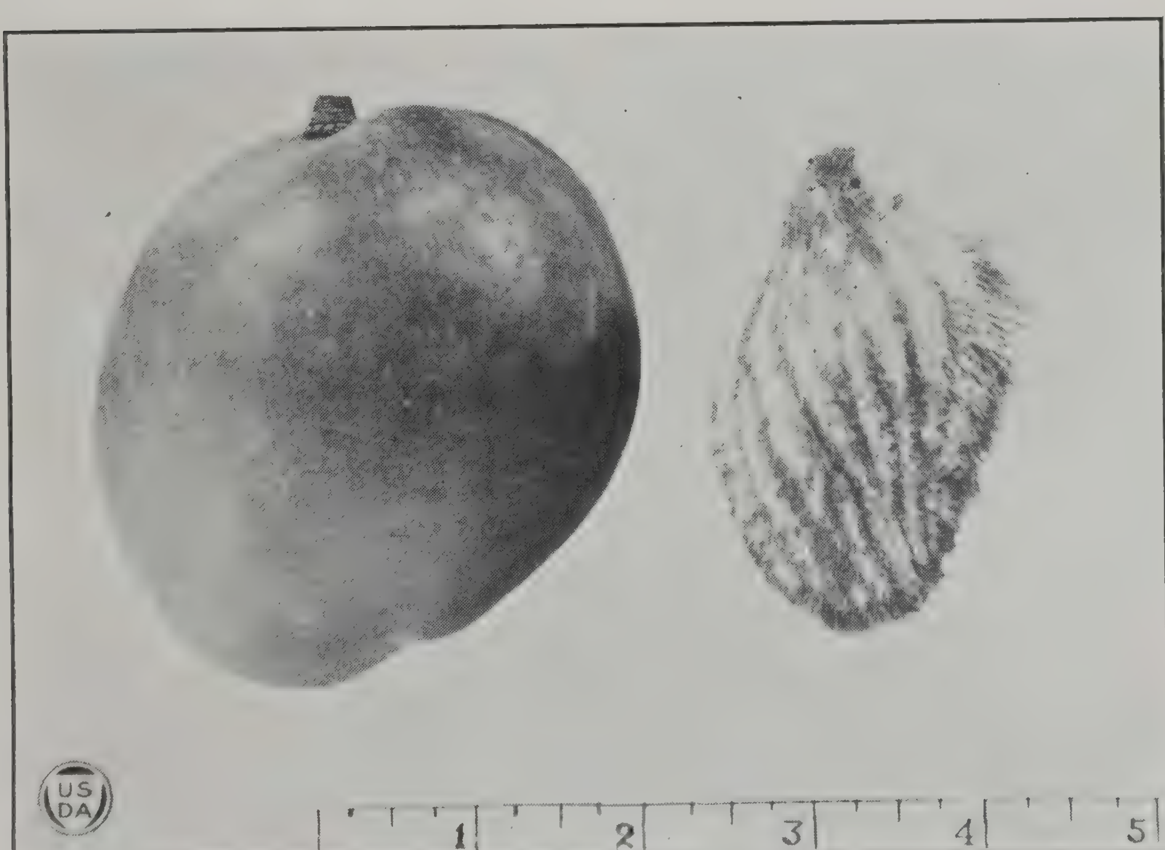


FIG. 2.—KALIHI MANGO. QUALITY EXCELLENT.

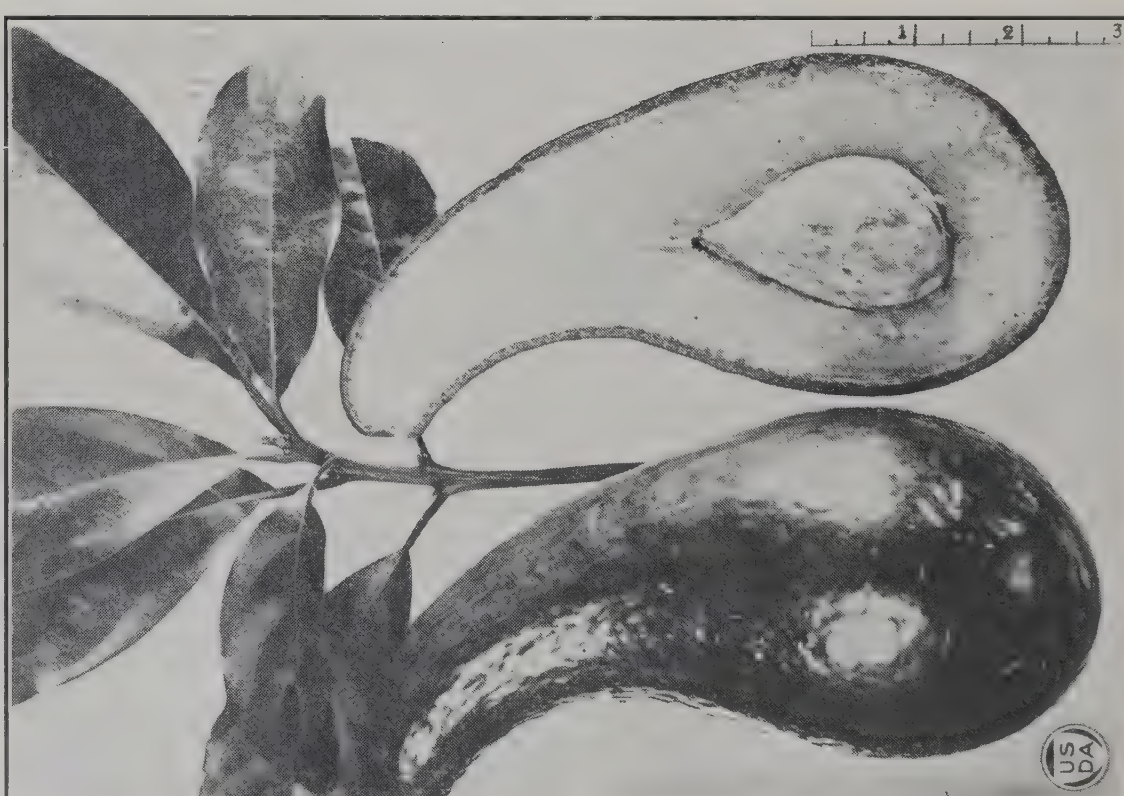


FIG. 1.—CASE AVOCADO.

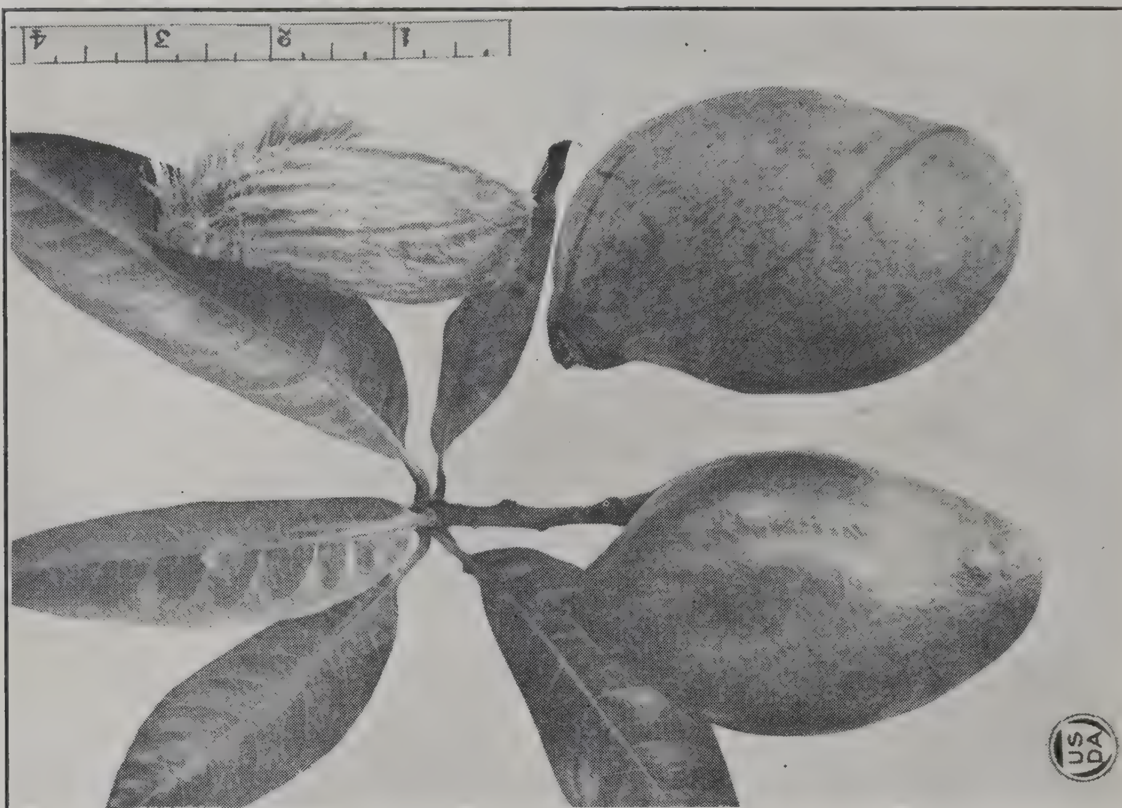


FIG. 2.—HAWAIIAN HYBRID MANGO (VICTORIA).

soil with infrequent irrigation. The crop was given only three light irrigations and two cultivations from the time of planting to the last harvest.

Mammoth Long Red and Champion Yellow Globe made the highest yields, producing 26.6 and 27.7 tons, respectively, of roots in 4 months and 11 days after planting. These varieties were not only heavy yielders, but they also made luxuriant growth and were fairly resistant to drought.

CORN.

Corn investigations were again confined to breeding and the stabilization of a yellow strain of Guam corn. Careful selection of ears conforming in every character except color to the original white variety has resulted in the production of a large number of well-shaped ears showing uniformity of color and type of kernel.

In a hybridization experiment, undertaken in conjunction with the sweet corn investigations, a hybrid white Guam corn was used as the mother and the Henderson Sweet as the staminate parent. The former was planted in alternate rows with the latter and was detasseled at tasseling time. The hybrid cornstalks, representing 75 per cent sweet and 25 per cent Guam stock, are making vigorous growth and the kernels are in the dough stage (June 30, 1922).

FORAGE CROPS.

GRASSES.

Large distributions of cuttings of Napier grass (*Pennisetum purpureum*) and Merker grass (*P. merkeri*) were again made during the year to dairymen and farmers, and approximately 1½ acres were planted with these grasses for the production of cuttings for immediate delivery.

In conjunction with the improvement of forage crops, plantings were made of individual seedlings of Merker grass, giving indications of quality, heavy stooling, and rank growth.

In a comparative test of Napier grass, sugar cane, and kafir corn, Merker grass made the highest yields, producing 47.95 tons of green forage in two cuttings. The yield of Napier grass in the second cutting undoubtedly would have been higher had not Uba cane been grown close to it on one side and Merker grass on the other. The following table gives the results of the test:

Yield of eight forage crops which were planted May 7, 1921.

Crop.	Yield per acre. First cutting, Nov. 7, 1921.	Yield per acre. Second cutting, Apr. 7, 1922.	Crop.	Yield per acre. First cutting, Nov. 7, 1921.	Yield per acre. Second cutting, Apr. 7, 1922.
	Tons.	*Tons.*		*Tons.*	*Tons.*
Yellow Caledonia sugar cane	10.54	13.02	Uba sugar cane	23.17	23.82
Lahaina sugar cane	9.84	3.13	D-1135 sugar cane	13.94	12.35
Merker grass	23.52	24.43	109 sugar cane	2.11	3.39
Napier grass	19.16	6.44	Kafir corn	7.92	11.02

Natal redtop (*Tricholæna rosea*), Australian blue (*Andropogon sericeus*), Australian water grass (*Paspalum dilatatum*), Wilder grass (*Andropogon* sp.), and fuzzy top (*A. saccharoides*), which were planted in the demonstration plats in July, 1915, yielded in two cuttings, 7.7, 8.58, 6.43, 4.32, and 6.16 tons, respectively, of green forage. The relatively low yields were due to abnormal growth resulting from continuous cropping through seven years and consequent root binding. Data obtained from this protracted experiment show that about four years is the period of greatest usefulness of these grasses for pasture purposes.

A nonirrigated test was made of Tunis grass (*Andropogon sorghum*), Sudan grass (*Andropogon* sp.), Wonder Forage (*Andropogon* sp.), and *Panicum antidotale* from July 30, 1921, to April 3, 1922. Yields were about one-third of what could presumably be obtained with irrigation.

Panicum setosum and *P. complanatum*, planted July 7, 1921, yielded on October 28 at the rate of 50.9 and 6.7 tons, respectively, of green forage per acre. *P. setosum* is a rank growing grass and attains a height of 3 feet under normal conditions.

Exophorus unisetus and Guatemala grass (*Tripsacum laxum*), two new grasses tested during the year, have been found to be valuable additions as feed for livestock. The former is an erect grass and attains a height of 2½ feet to 4 feet. Its stems and leaves are of excellent quality. At the station this grass produced at the rate of 44.6 tons of green forage per acre, and large quantities of the seed were distributed to those interested in the improvement of Hawaiian pasture grasses.

Guatemala grass (Pl. VII, fig. 1) was cut for the first time July 26, 1921, when it yielded at the rate of 46.5 tons of green forage per acre. In an experiment made to determine whether this grass could be grown by cuttings, it was found that 60 per cent of the cuttings took root and developed into vigorous plants, 10 per cent developed but died later, and 30 per cent failed to develop.

SORGHUMS.

Four varieties of grain sorghum were tested for their green forage value during the year. An African variety, No. 309, produced 6.68 tons in 4½ months, while kafir, Amber cane, and Egyptian corn yielded 6, 8.9, and 4.9 tons, respectively, of green forage in three months.

KALE.

Jersey and Giant Marrow were planted to obtain data as to their yield and adaptability to poultry rations. Of the two varieties, Giant Marrow made the heavier yield, exceeding Jersey by 5.8 tons in the first harvest, 10 in the second, 5.1 in the third, and 8.9 in the last.

Many large plants of the Giant Marrow variety succumbed to the attacks of the larvæ of the melon fly.

LEGUMINOUS CROPS.

COWPEAS.

During the year station hybrid No. 1383, planted primarily for the production of seed, yielded approximately 200 pounds of clean seed from three plantings. Individual plants that were observed to be outstanding in rankness of growth, heaviness of foliage, and prolificacy, were selected for future work.

HUBAM CLOVER.

Hubam clover, planted on one-tenth acre for forage and seed production, yielded at the rate of 12.4 tons per acre on one-twentieth acre for a growing period of three months. The rest of the plat produced 22.5 pounds of hulled seed, or at the rate of 450 pounds per acre.

SUNN HEMP.

Work with sunn hemp (*Crotalaria juncea*) was confined to the selection of plants producing heavy foliage and many pods in the hope of improving the variety in these two characters.

DISTRIBUTION OF SEEDS AND CUTTINGS.

The number of seeds and cuttings distributed by the agronomy division during the year slightly exceeded that of the preceding year. For the 12 months ending June 30, 1922, the distributions were made in amounts as follows:

Seeds and cuttings distributed during the year ending June 30, 1922.

Crop.	Seeds.	Cuttings.	Crop.	Seeds.	Cuttings.
	Pounds.	*Number.*		*Pounds.*	*Number.*
Napier grass	4	55,412	Edible canna "tubers"		12,504
Giant Bermuda grass		2,136	Cassava		2,416
Merker grass	4	2,822	Corn	195	
Natal redtop grass	8	24	Pigeon peas	109	
Sudan grass		26	Peanuts	37	
Java grass		12	Beans	30	
Kulthi grass		8	Mungo beans	32	
Kikuya grass		4	Kale	½	
Tunis grass		2	Alfalfa	8	
Australian blue grass	1		Hubam clover	6	
Wonder Forage	4		Cotton seeds	2	
Molasses grass	1		Kudzu (rooted cuttings)		130
Buffalo grass [1]		3,000	Sorghum	1	
Uba cane		8,700	Sunflowers	1	
Honohono		25	Field turnips	1	
Sweet potatoes		8,408	Egyptian corn	1	

[1] Hawaiian variety.

POULTRY.

Judging from the nature and number of inquiries received, it is thought that poultry raisers are coming to realize more and more that intelligent culling is a deciding factor in profitable poultry production. A number of articles published by the agronomist in one of the local newspapers have undoubtedly stimulated this phase of the work.

Early in July, 1921, the station, working in cooperation with the Union Feed Co. (Ltd.), sent the writer to the mainland to study the poultry industry in the Haywood and Petaluma districts, California, and at the Agricultural College and Hanson Poultry Farm, Oregon. Two hundred and thirty yearling White Leghorn hens and cockerels and 31 Barred Plymouth Rock hens were purchased and taken to Honolulu by the writer. The White Leghorn hens selected were bred for high-egg production, having first-year trapnest records ranging from 250 to 298 eggs. The cockerels were immediate descendants of hens having a trapnest record of 304 to 307 eggs for their first year. The Barred Plymouth Rocks, purchased for patrons of the feed company, were closely related to a hen which had laid 324 eggs in 365 consecutive days at the California farm bureau egg-laying contest in Santa Cruz. All of the fowls were examined for characteristics indicating heavy egg-laying capacity and to make certain that they were free from disease, and a study was made of each fowl's pedigree. Shortly after their arrival in Honolulu, the Leghorns were graded and placed in four separate pens according to their egg records.

The agronomist also assisted in establishing a poultry plant at the United States Marine Corps Barracks, Pearl Harbor.

Sorehead (*Epithelioma contagiosum*) was very prevalent in some of the poultry yards during the year and caused heavy losses on Oahu in spite of the precautions taken. (Pl. VIII, figs. 1 and 2.) During the coming year it is hoped that sufficient time can be found to permit of the study of this disease relative to its prevention and cure.

Coccidiosis, a common poultry disease, appeared in two flocks in a new form, and the poultry succumbed without warning. On post-mortem examination the respiratory and digestive organs were found to be normal, except the cæca, which were distended and filled with coagulated blood. (Pl. VIII, fig. 3.) This disease was mentioned as an unidentified disease in last year's report.[1]

As soon as the disease is detected in the flock, crude catechu should be placed in the water given the birds to drink (one-third teaspoonful of the former to 1 gallon of the latter) for a period of one week, or until the birds regain their normal condition.[2]

REPORT OF THE CHEMICAL DIVISION.

By J. C. Ripperton.

COOPERATIVE FERTILIZER EXPERIMENTS.

BANANAS.

The great possibilities of banana growing on a commercial scale seem to warrant the undertaking of a series of rather intensive fertilizer experiments in connection with this crop. Tests are being made to determine the effect on the crop of applying fertilizers in single and fractional doses throughout the growing season, as well

[1] Hawaii Sta. Rpt. 1921, p. 35.
[2] U. S. Dept. Agr. Farmers' Bul. 957, Important poultry diseases, p. 23, 24.

FIG. 1.—GUATEMALA GRASS (TRIPSACUM LAXUM).

FIG. 2.—PIGEON PEAS. CENTER NOT FERTILIZED: BOTH SIDES RECEIVED FERTILIZER.

FIG. 1.—SOREHEAD, MILD FORM.

FIG. 2.—SOREHEAD, SEVERE.

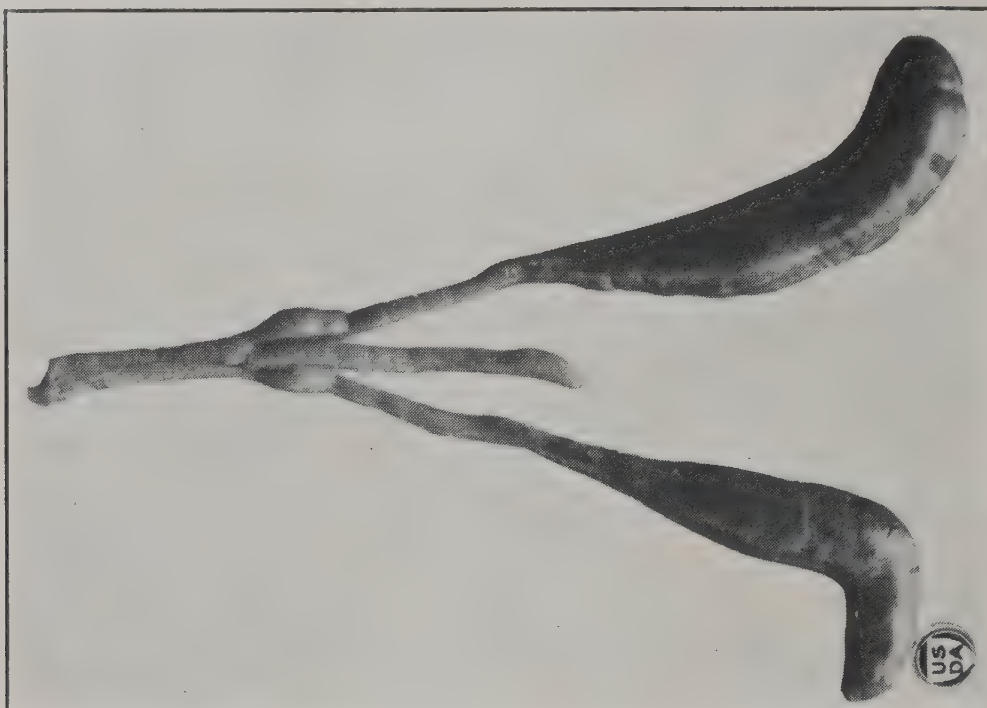


FIG. 3.—CÆCA OF PULLET DISTENDED WITH COAGULATED BLOOD, RESULT OF COCCIDIOSIS.

as the effect of leaching by irrigation waters on fertilizers applied in different parts of the ridge or furrow.

Three crops of bananas, harvested from the triangular fertilizer experiments,[3] failed to show any appreciable increase in weight or number of bunches due to fertilizer. Observation of the drainage ditches, opened to prevent water logging, showed a rapid downward percolation of the irrigation water, and the percolates were found to contain appreciable quantities of all the fertilizer salts applied.

Examination of the roots of a number of plants which were dug at different stages of maturity showed that the banana is essentially a surface feeder. Root hairs were found only on the upper whorl of roots except in case of plants two months of age or less. Some of the more vigorous plants had two whorls of feeding roots, but the lower roots were in a dormant or half-decayed condition. In Hawaii, where the banana is planted in a trench about 2 feet deep and the feeding roots extend outward almost horizontally into the ridges in consequence, it would seem that the fertilizer should be applied close to the surface.

In December, 1921, six half-acre plats were laid off and planted to bananas to determine the best method of applying fertilizer to the crop. In the first plat the total quantity of fertilizer was hoed in around the base of the plants immediately before irrigation; in the second plat a small trench was dug around the plants and the total quantity of fertilizer was hoed in the sides of the ridge and at about the level of the water during irrigation, so that capillary water only would reach the fertilizer; in the third plat one-sixth of the total quantity is being applied each month about the base of the plants and hoed in immediately before irrigation; and in the fourth plat one-sixth of the total quantity is being applied each month about the base of the plants immediately after the irrigation water sinks below the surface of the trench. The two remaining plats are serving as checks.

The same kind and quantity of fertilizer is being used in each plat. The fertilizer is made up chiefly of water-soluble salts, with nitrogen, phosphoric acid, and potash in the proportions of 6, 12, and 7 per cent, respectively, and it is being applied at the rate of 1,500 pounds per acre, which is equivalent to 1.5 pounds per plant.

Drainage ditches have been cut to permit of a comparison of the seepage water from the different plats, and it is expected that a series of percolation experiments will be carried on for the purpose of comparing the quantities of fertilizer leached out under the different methods of application.

PINEAPPLES.

In 1919 ten 0.1-acre plats at the New Era homestead farm were planted with 800 pineapple shoots each to determine the effect of fertilizer on pineapple wilt. The first application was made two weeks after planting, and the second, a supplementary one consisting of one-fourth the original quantity, was made on half of each fertilized plat one year later. Fertilizer was found to exert little or no effect on the crop, the last harvesting cycle of which was completed

[3] Hawaii Sta. Rpt. 1920, p. 34.

in August, 1922. The field was infested with pineapple wilt before the plant crop was harvested, and plats Nos. 1 and 2 were so severely damaged that less than half the plants produced matured fruit. The following table gives the yield of the plats as a whole:

Yield and weight of pineapple plant crop, grown with and without fertilizer, at Haiku.

Plat No.	Fertilizer treatment per plat.			Number of fruits harvested per plat.	Total weight of fruits per plat.	Average weight per fruit.
	Nitrogen mixture.[1]	Acid phosphate.	Potassium phosphate.			
	Pounds.	*Pounds.*	*Pounds.*		*Pounds.*	*Pounds.*
1	75			279	1,260	4.51
2	50	31		301	1,457	4.84
2 (check)[2]				455	2,361	5.18
3	50		8.3	527	2,699	5.12
4	25	58.3		484	2,536	5.24
4 (check)[2]				533	2,846	5.34
5	25	31	8.3	546	2,804	5.13
6	25		16.6	608	3,147	5.17
6 (check)[2]				632	3,245	5.13
7		87.5		554	3,034	5.47
8		62	8.3	524	2,842	5.42
8 (check)[2]				530	2,665	5.02
9		31	16.6	537	2,898	5.39
10			25	514	2,875	5.59

[1] Ammonium sulphate, 45 per cent, and sodium nitrate, 55 per cent.

[2] No fertilizer.

In considering the results it should be borne in mind that the field became severely infected with pineapple wilt, and, as is shown by the high average weight of the fruit produced on the check plats, the soil was exceptionally fertile and would not therefore respond to fertilizer treatment as would poorer soil. The experiment shows that neither the fertilizers used nor the vigorous growth made by the crop was able to ward off the wilt. The experiment was discontinued with the final harvest.

UPLAND SUGAR CANE.

In order to determine the effect of fertilizer on yield, Yellow Caledonia upland sugar cane was planted October, 1919, at Haiku on 26 plats, each one-tenth of an acre in size, which had previously been cropped with pineapples. Nonirrigated sugar cane, which has the same cycle of productive growth as the pineapple and yields as high as 6 tons of sugar per acre, gives promise as a profitable crop for rotating with pineapples in certain sections. Three rows were made to a plat. The first fertilizer was applied October 15, 1919, and about a month later two rows of each fertilized plat were given a supplementary application equaling one-fourth the quantity applied the first time. The year following planting was exceptionally dry and the cane made very little growth. The second year, however, had normal rainfall and the growth was rapid, but harvesting was delayed until the spring of 1922. Since the crop showed no effect of the supplementary application, only the yield of the plats as a whole are given in the following table:

Yield of upland sugar cane at Haiku.

Plat No.	Fertilizer treatment per plat.			Yield per plat.		Calculated increase per acre, due to fertilizers.	
	Nitrogen mixture.[1]	Acid phosphate.	Potassium sulphate.	Cane.	Sugar.	Cane.	Sugar.
	Pounds.	*Pounds.*	*Pounds.*	*Tons.*	*Tons.*	*Tons.*	*Tons.*
1[2]	75			2.27	0.289	4.50	0.573
2	60	20		2.75	.350	.30	.038
3 (check)[3]				2.72	.346		
4	60		5	2.81	.358	.86	.110
5	45	40		3.19	.407	4.62	.589
6	45	20		3.11	.396	3.78	.482
7	45		10	3.17	.404	4.34	.553
8 (check)[3]				2.74	.349		
9	30	60		3.01	.384	3.58	.456
10	30	40	5	2.84	.362	2.76	.352
11	30	20	10	3.01	.384	5.34	.680
12	30		15	2.74	.349	3.52	.448
13 (check)[3]				2.30	.293		
14	15	80		2.78	.354	3.98	.507
15	15	60	5	2.84	.362	3.76	.479
16	15	40	10	2.74	.349	1.94	.247
17	15	20	15	2.90	.369	2.72	.345
18 (check)[3]				2.71	.345		
19	15		20	3.08	.393	3.68	.469
20		100		3.05	.389	3.36	.428
21		80	5	3.44	.438	7.24	.922
22		60	10	3.33	.425	6.12	.780
23 (check)[3]				2.72	.346		
24		40	15	2.97	.378	2.50	.318
25		20	20	3.02	.385	3.00	.382
26			25	2.76	.352	.40	.051

[1] Ammonium sulphate, 45 per cent, and sodium nitrate, 55 per cent.
[2] Damaged by cattle.
[3] No fertilizer.

The above table shows that distinct increases resulted from the fertilizer treatment, but there appears to be no relation between the amount of increase and the composition of the fertilizer applied. Phosphoric acid was the only single fertilizer giving an appreciable increase, and plats 21 and 22, which received this element in fairly large quantities, made the highest yields.

FERTILITY-ROTATION EXPERIMENT.

During the year the pigeon-pea crop was plowed under and both the pineapple and sugar cane plant crops were harvested. The unusually severe drought of 1919–20 caused these two crops to make small yields, and very little effect could be attributed to the fertilizer treatments. The pineapple plat receiving nitrogen mixture (sodium nitrate, 55 per cent, and ammonium sulphate, 45 per cent) at the rate of 400 pounds per acre was very perceptibly greener and sturdier than the adjacent plats. The fruit averaged one-half pound heavier than that from the check plat. The plat receiving nitrogen mixture and potassium sulphate at the rate of 400 and 200 pounds, respectively, per acre responded equally well. This experiment will be continued.

PRESERVATION OF HAWAIIAN FRUITS.

During the year an intensive study was made of the guava, grape, and roselle for the purpose of developing a systematic procedure for making jelly from any kind of tropical fruit containing pectin and

acid. The results of this investigation have been submitted for publication.[4] Cooperative work with a local company with a view to standardizing the juices used for jelly making was continued, and the methods developed in the foregoing study are proving practicable for jelly making on a commercial scale.

Additional products having especial commercial possibilities are dehydrated mango, from which an excellent candied fruit can be made; dehydrated papaya, which mixed with lemon makes a cheap but excellent jam; and dehydrated guava, from which jelly can be made.

MINERAL CONSTITUENTS OF HAWAIIAN VEGETABLES.

Certain classes of people in Hawaii are of the opinion that locally grown vegetables are lacking in lime, iron, and other essential mineral constituents, and that they are not, for that reason, as good as the imported vegetables. Results of an experiment, conducted to determine the mineral constituents of the more common locally grown vegetables, show that Hawaiian-grown vegetables are as high in mineral content as the imported. The following table gives the results of a preliminary test made to determine the mineral constituents of spinach and cabbage, which are commonly found on the markets of the mainland, as compared with those of the locally grown cabbage and Chinese spinach:

Comparison of mineral constituents of Hawaiian and mainland grown spinach and cabbage.

[Calculated as percentages of dry material.]

Vegetable.	Where grown.	Total ash.	Phosphoric acid (P_2O_5).	Ferric oxid (Fe_2O_3)	Potash (K_2O).	Lime (CaO).
Spinach (canned)	California	20.82	0.97	0.048	3.92	0.90
Spinach (dehydrated)	Oregon	22.16	1.90	.075	7.65	.82
Spinach (fresh)	Hawaii (Honolulu)	23.36	1.97	.102	7.11	2.85
Do	do	17.60				2.92
Do	do	21.34				2.82
Do.[1]	Virginia	20.68	1.33	.090	8.60	1.14
Cabbage (fresh)[2]	Ohio	7.19	.59		3.01	.83
Do	Hawaii (Oahu)	9.13	.98	.045	3.20	.93

[1] Jour. Agr. Research, v. 16, No. 1, p. 17.
[2] Ohio Agr. Expt. Sta. Bul. 255, p. 226.

Some of the variations in results may be due to lack of uniformity in the variety of vegetable tested, and in the case of the California sample loss of some of the mineral constituents may have occurred during the process of canning. The results show, however, that locally grown spinach and cabbage are equal, if not superior, to the commonly imported brands in the important mineral constituents.

Carrots, beets, cabbages, spinach, string beans, and peas have been planted in two widely separate localities on the mainland (Virginia and Washington State), and also in two localities on Oahu in order that a comparison may be made of their nutritive constitutents. All four series are to be harvested at the same stage of maturity and

[4] Hawaii Sta. Bul. 47, Application of the principles of jelly making to Hawaiian fruits.

then dried. Any difference in composition of each crop will doubtless be due to the soil and climatic conditions prevailing at each place, since the seed stock is the same.

HAWAIIAN STARCHES.

TREE FERN.

Three experimental plats have been established at different altitudes along the Volcano Road to determine the feasibility of replanting the tree fern for starch production on cut-over areas. At the end of 9 months 85 per cent of the plantings were growing, including crowns, and large and small lateral shoots of the several varieties.

Rate of growth of the tree fern has been learned by measuring the vertical distance between the frond pits on the same "spiral." A complete circle of fronds averaging five in number develops at one time and each frond of the circle represents one of the spirals on the trunk. Since probably only one circle of fronds is developed in a year, it is concluded that the annual vertical growth is about 4 inches.

EDIBLE CANNA.

Complete chemical analyses are being made each month of samples of edible canna to determine at what stage of growth the tubers will yield the maximum amount of starch, and an experiment is being conducted in cooperation with a company in Hilo to study the commercial possibilities of the crop. In June, 1922, edible canna was planted in 36 plats, each one-tenth acre in size, to determine its fertilizer requirements. The plats are 18 miles from Hilo along the Volcano Road, where the elevation is 2,000 feet, and the soil is somewhat thin, being underlain by undecomposed lava at a depth of a few inches to several feet. The first application of fertilizer will be made in July, 1922, and the results of the experiment reported upon next year.

Small plats of canna have been planted along the Volcano Road at elevations varying from 300 to 3,500 feet to learn the highest altitude in which the crop can be successfully raised. Monthly harvests are to be made of 10 hills on each plat to ascertain the rate of growth and maximum yield.

EFFECT ON CROPS OF BRACKISH IRRIGATION WATER.

Studies are being continued to determine the tolerance of various crops to brackish irrigation water. Three crops, alfalfa, rice, and Napier grass were planted in lysimeters, and after germinating and reaching a height of 2 inches in fresh water were given measured quantities of water containing varying amounts of sodium chlorid. The percolates were collected and the sodium determined. Alfalfa was found to withstand a greater percentage of salt when once well established than when it was in the seedling stage.

Many soils which have been watered continuously with salty irrigation water are showing evidence of considerable accumulation of salt. It is planned to repeat the above-mentioned experiment with a second crop to learn what this cumulative effect in the soil is. It

is also planned to visit all the important irrigated sections of the islands to learn the salt content of the well water used in each district, the salt accumulation in the soil, and the kind and condition of crops being grown. The results should furnish a valuable guide for each district as to the limit of salt in the water, the danger of its accumulation, and the salt tolerance of all the common crops.

REPORT OF EXTENSION AND DEMONSTRATION WORK ON THE ISLAND OF HAWAII.

By R. A. Goff.

SOILING CROPS FOR PLANTATIONS.

The majority of the plantation owners, having enlarged their dairies or established new ones for the purpose of providing their laborers with milk at cost, are interested in the question of feeds for dairy stock. Pigeon peas and Napier grass are apparently the two crops best adapted to this purpose, as they produce a number of ratoon crops before it is necessary to replant, withstand the heavy rains and occasional dry periods of the district equally well, and form a balanced ration with the addition of very little imported milled feeds. Distribution of seeds and cuttings of these crops has been made to various plantations, and every assistance has been given to those who are interested in planting.

SCHOOL AND HOME GARDEN WORK.

The extension agent acted as one of the judges in the Star-Bulletin school-garden contest in the districts of Kau, Kona, Waiamea, and Kohala, and in the smaller contests in the outlying districts of Hamakua and Puna. Three visits were made to each of 11 schools and 35 home gardens, the pupils accompanying the judges in each instance to the gardens to discuss insect pests, seed varieties, and fertilizers.

COOPERATION WITH BOY SCOUTS.

The extension agent has served as scout commissioner for the island since January, 1922. He has given a number of talks on natural history and gardening to the scouts at schools in the country and has taken the boys on hikes to various plantations and homesteads to instruct them in the use of farming implements.

WORK IN WAIAMEA DISTRICT.

In 1922, A. W. Carter, manager of the Parker ranch, set aside 16 acres as a demonstration plat for the raising of crops of benefit either to the ranch or to local homesteaders. The work is carried on under the direction of the extension agent, and the labor, farming implements, and work animals are furnished by the ranch. Over 50 varieties of seed were supplied by H. L. Chung, of the central station, and as many more were ordered from the States, Australia, and England by Mr. Carter. Most of the plantings have

been failures so far, due to the elevation (2,700 feet) and to the prevailing heavy winds of the district. Corn (three varieties), potatoes (two varieties), forage crops (eight varieties), beets (four varieties), grasses (seven varieties), and clover (two varieties) are apparently doing well, however. Many homesteaders are interested in the project and are making inquiries about the different varieties being tried.

WORK IN KOHALA DISTRICT.

Through the efforts of the extension agent, many seedling trees were obtained from the local nursery of the Board of Agriculture and Forestry for planting as windbreaks in the district of Kohala. Fruit trees were pruned, plantings distributed, and talks given to groups of interested homesteaders who have considerable area in pineapples.

WORK IN KONA AND KAU DISTRICTS.

During the year the extension agent ordered seed of brome and rye grasses, pigeon peas, and bur and sweet clover, which have done well elsewhere on Hawaii, for the owners of cattle ranches in the districts of Kona and Kau, where they are being tried for the first time. The crops have been planted in plats and broadcasted in pastures and should help to improve the land.

A dairy is planned in connection with the junior high school at Kealekekua, Kona, and purebred Holstein cattle have been promised by the Parker ranch when an additional 10 acres, adjoining the school property, is secured and the buildings are up. Seeds and cuttings of Peruvian and Grimm alfalfa, Napier grass, Waiamea white corn, Boone County White and Reid's Yellow Dent corn, pigeon peas, and *Paspalum dilatatum* have already been planted so as to provide some of the necessary feed for the cattle when they arrive. The boys of the school are raising the crops. Two ranchers of the district have already asked for seed of some of the crops which they have seen growing at the school.

GLENWOOD SUBSTATION AND DEMONSTRATION FARM.

The number of livestock is being rapidly increased in the Glenwood district, and animal raising is being depended upon for profitable returns owing to the difficulty of raising marketable crops. Forage crops which can be fed green are being grown, and Australian water grass and bur clover are being broadcasted to improve the pastures rapidly.

The dairy herd of the substation consists of 14 milk cows and 20 heifers and calves, which will be headed by a recently purchased purebred Holstein bull calf. In addition to this herd there are on hand 1 purebred Berkshire boar, 3 Berkshire sows, and a poultry flock, which is increasing at the rate of 100 laying hens a year.

The farm was established for the purpose of demonstrating that 50 acres of well-stocked land in the Glenwood district can be made to support a family. It has done good work, and in the opinion of X. L. Helbush, the collaborator in immediate charge, the projects should be brought to a satisfactory close during the coming year.

FRUIT TREE NURSERY.

In 1921, 2,000 avocado and 500 mango seedlings were planted for the purpose of budding and grafting some of the better varieties of these trees for free distribution. With the assistance of C. E. Vaile, agriculturist at the Hilo Boarding School, 650 of the avocado seedlings were budded with wood from winter bearing trees in Hilo, and about 400 more are being budded with material sent from the central station. The remaining avocado and all of the mango seedlings will be worked over this summer as they become of sufficient size. Papaya seedlings have been distributed and some 800 rough lemon and shaddock seed planted for stock for grapefruit and orange budding.

REPORT OF HOME DEMONSTRATION ACTIVITIES.

By Mrs. N. A. Russell.

During the summer and autumn of 1921 the home economics demonstrator, acting in cooperation with the social welfare bureau, made weekly visits to one of the local pineapple canneries, where she instructed groups of 22 to 75 Japanese, Chinese, Philippine, Portuguese, and Hawaiian women in the growing and use of fruits and vegetables. At least one practical recipe was worked out for each fruit or vegetable, and samples of the prepared dishes were given to those attending.

In cooperation with the housewives' league, she gave an hour's talk each month, followed by demonstrations, on the utilization of meats, vegetables, and fruits of the Hawaiian Islands. This group of women is largely of American parentage, and as many as 100 attended some of the meetings.

Demonstrations of the making of papaya and tomato products were given in cooperation with the educational committee of Wahiawa for the benefit of the boys and girls of the seventh and eighth grades. Fully 48 children and 7 adults attended each meeting.

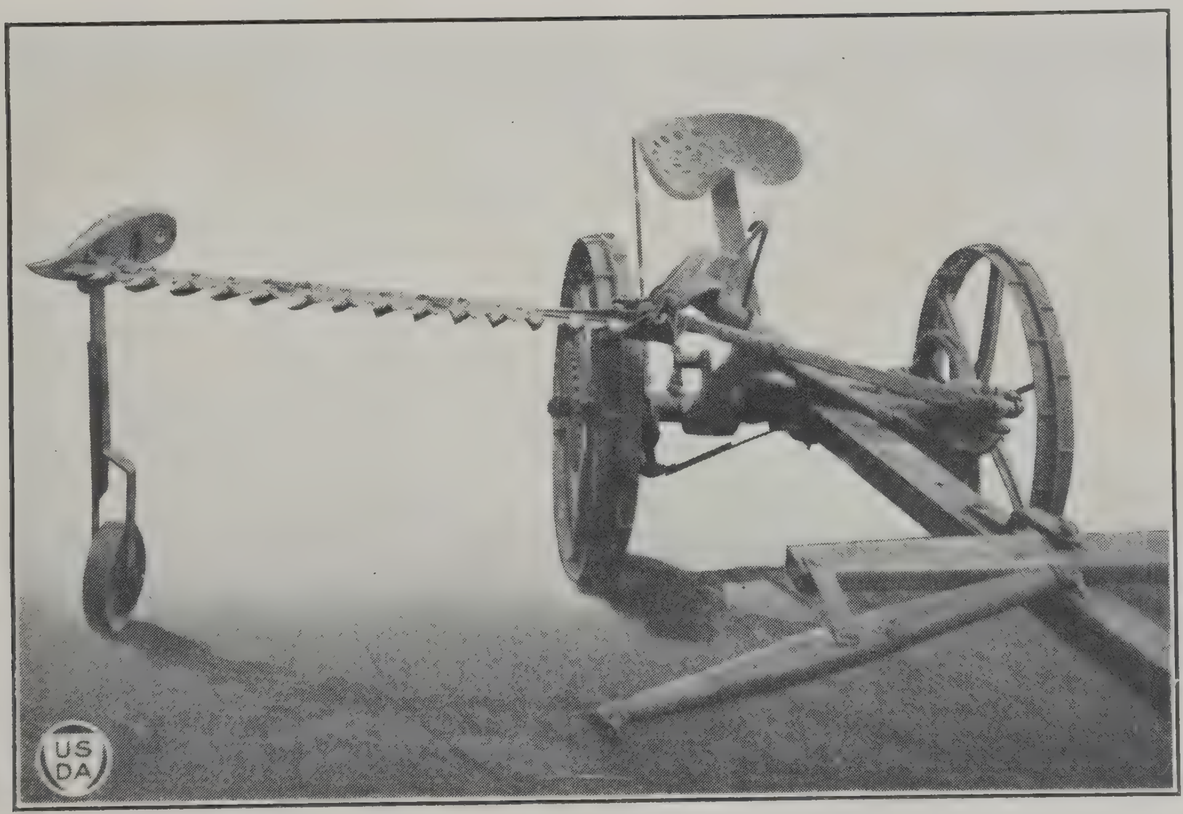
HAIKU SUBSTATION AND DEMONSTRATION FARM.

By F. G. Krauss.

PIGEON PEAS.

Probably no other crop in Hawaii lends itself so readily to a large variety of conditions as does the pigeon pea. Fully 10,000 acres are under cultivation in Hawaii, and fully 25 tons of the seed, or enough to plant 5,000 acres, was distributed during the year, large quantities being sent to Guam, Australia, New Zealand, East Africa, California, and Florida. The adaptability of the crop to very sandy and somewhat saline beach lands has been fully demonstrated.

Under average field conditions pigeon peas as pasturage may be expected to carry from one to two and one-half head of cattle per



MOWER ADAPTED FOR CUTTING PIGEON PEA FORAGE.

acre for two 100-day periods, or during the normal seeding stage of the crop. An acre of pigeon peas under good average conditions should produce from 300 to 1,000 pounds of prime beef per annum. The same lands in ordinary grass pasture frequently carry less than one head for 2½ to 5 acres.

The following table gives the relative yield per acre of ordinary field crops of pigeon peas with and without irrigation:

Comparative yields per acre of pigeon peas, grown with and without irrigation.

[Seven months after planting.]

Parts of individual plant.	Nonirrigated field.	Irrigated field.
	Pounds.	*Pounds.*
Whole plant (including roots)	32,500	82,900
Forage	11,400	30,560
Seed (shelled)	1,120	1,623

These data were compiled from results obtained by a sugar company in Maui and from the University Farm, Manoa Valley, Oahu. The Maui soil is very sandy and somewhat saline. The Oahu soil is a heavy, gravelly loam. Both soils are extremely dry in summer and produce very few crops without irrigation. The above table shows that under the conditions noted greatly increased crop yields may be expected from irrigation.

PIGEON-PEA FERTILIZER EXPERIMENT.

In a fertilizer experiment, conducted at Pupukea on raw uplands failing to produce more than 2 or 3 tons of pineapples per acre and only very few other crops, a fertilized plat yielded 13.07 tons of green forage, compared with 2.61 tons produced by an unfertilized plat. (Pl. VII, fig. 2.) The results show that under the unusual conditions presented in this case fertilization is essential and profitable for the production of even moderate yields. Phosphatic fertilizer was applied at the rate of 500 pounds per acre in the drill at the time of planting at a cost of about $12 per acre.

IMPROVED EQUIPMENT FOR THE CROP.

Judging by the new and improved machinery now being devised by various pigeon-pea growers, it would seem that a well-designed pigeon-pea equipment should be available for use within the year. Through the ingenuity of E. Falk, farm superintendent for Dr. W. D. Baldwin, Haiku, Maui, an ordinary mowing machine has been adapted to cut pigeon-pea forage. (Pl. IX.) The cutting bar of the mower is elevated to cut at a height of about 30 inches, the tongue or pole being moved to the center of the frame, the forepart of which is lifted at the same time to the desired height. This is done automatically by placing the pole under instead of over the frame. The pole is held firmly in place by a strong supplementary iron clamp. A seeder having fertilizer attachment has been devised by L. E. Arnold to facilitate the work of planting large areas of pigeon peas.

PINEAPPLES.

Pineapple growers are giving every attention to improved cultural methods and to careful breeding work through bud selection. Far better tillage is being practiced than formerly, and green manuring crops are being plowed under with excellent results over widely different conditions. It is thought that pineapples can be made to follow sugar cane satisfactorily. At Haiku a 5-acre field in which pineapples are following cassava is doing well.

Substantial advances are being made in the use of commercial chemical fertilizers, 500 to 1,000 pounds of which are being applied in the drill at the time of planting, followed by supplementary doses of ammonium sulphate throughout the growth of the crop. These later applications may be applied as a spray or top or side dressing. Spraying with iron-sulphate solutions with or without ammonium sulphate has become a common practice on manganiferous soils. Possibly one of the most radical and far-reaching practices inaugurated in connection with pineapple culture in recent years is the introduction of the paper mulch. It is as yet too early to predict its final outcome.

HALEAKALA SUBSTATION AND DEMONSTRATION FARM.

By J. F. O'Brien.[5]

MISCELLANEOUS PLANTINGS.

During the year about 30 different crops were tested either in small plats under different quantities of fertilizer or under field conditions. Ten acres each of cowpeas and soy beans and 1 acre each of 10 different varieties of corn were planted for trial. The low night temperature at this elevation (1,800 feet) is not conducive to the best production of corn, and the crop was forced to grow with less than 2 inches of rainfall a month. The most successful field crops are those thriving during the cool rainy season from September to March and ripening during the hot, dry season of June and July.

The pigeon pea has proved its adaptability to conditions at the Haleakala demonstration farm, and its seed has assisted materially in furnishing feed for turkeys.

Seed of the purple vetch, inoculated and planted November 12 on a freshly cleared plat, made excellent growth, yielding 10 tons of green forage per acre within 100 days after planting. The second growth was nearly as heavy as the first and required about 200 days in which to mature its seed.

Emmer, planted in December, 1921, survived the severe rain and wind storm that practically destroyed oats and other crops. It began heading 120 days after planting. Some acclimatization work will have to be done with this crop, but its showing in comparison with other grain crops is such as to make it take rank with the promising crops of the locality.

The Bellingham pea made excellent growth under field conditions, even though only lightly fertilized with equal parts of re-

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[5] Temporarily employed as collaborator.

verted and superphosphate. The crop matures in about 120 days. Plantings made in January gave the best results. By planting early in October and again in January, however, it is possible to obtain two crops from the same land within 12 months. These peas will not thrive in warm weather. They should be planted fairly thick, either broadcast or in rows from 2 to 3½ feet apart, and be kept well cultivated.

HALEAKALA TOMATO.

The Haleakala tomato, which has been especially selected and bred for its fly-resistant qualities, has for a number of years shown itself adapted to conditions on Maui. It shows a tendency to produce its fruit in clusters, bearing five and six rather large fruits at almost the same height on the stem.

MISCELLANEOUS FRUITS.

Carolina strawberries, planted October, 1921, made excellent growth, the berries being large and plentiful. In ordinary seasons planting should be made in September immediately after the heavy rains. The ground should be pulverized as deeply as possible, and enriched with stable manure (20 tons per acre). The plants should be kept cultivated.

It is thought that the wild variety of poha can be made to grow under cultivation with a corresponding increase in yield.

LIVESTOCK.

The station is maintaining a small herd of goats headed by a registered Toggenburg buck, Gretel's Son No. 1554. The entire local area is typical grazing land, and there is every indication that dairying can be successfully carried on. It is also felt that poultry and hog production may be made supplemental lines of work to other activities helping to make successful a number of self-supporting small farms in the vicinity.

HAWAII AGRICULTURAL EXPERIMENT STATION
HONOLULU, HAWAII

Under the supervision of the
UNITED STATES DEPARTMENT OF AGRICULTURE

REPORT OF THE HAWAII AGRICULTURAL EXPERIMENT STATION

1923

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HAWAII AGRICULTURAL EXPERIMENT STATION, HONOLULU.

[Under the supervision of the Office of Experiment Stations, United States Department of Agriculture.]

E. W. ALLEN, *Chief, Office of Experiment Stations.*

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[1] Resigned June 30, 1923. [2] Appointed April 14, 1923.

HAWAII AGRICULTURAL EXPERIMENT STATION
HONOLULU, HAWAII

Under the supervision of the
UNITED STATES DEPARTMENT OF AGRICULTURE

Washington, D. C. July, 1924

REPORT OF THE HAWAII AGRICULTURAL EXPERIMENT STATION, 1923.

CONTENTS.

SUMMARY OF INVESTIGATIONS.

By J. M. WESTGATE, *Agronomist in Charge.*

During the fiscal year 1923 the station continued its policy of fostering the development of diversified agricultural industries in the islands. Special attention was given to the production of staple food supplies which, in either the raw or manufactured state, can be exported at a profit during normal times or used to feed the local population in the event of calamity befalling the sugar and pineapple industries or of interruption of shipping.

The scientific work of the station consisted in solving problems arising in connection with the development of agricultural industries. Perhaps the most important problem solved is that of overcoming chlorosis of pineapples growing on manganiferous soils by spraying the leaves with a solution of iron sulphate. As a result of this one discovery the value of the output of pineapples is estimated to have been increased to date by $10,000,000.

In the horticultural division leading varieties of tropical fruits, including bananas, avocados, papayas, mangoes, and breadfruits are being improved by breeding work, and successful propagation methods are being worked out in connection with such fruits as fail to come true to seed. Results worthy of mention are being secured with varietal selections of figs, mulberries, strawberries, and the poha or husk tomato. During the year approximately 25,000 plants and packages of seed of improved varieties were distributed to cooperators throughout the islands.

Agronomic work was directed principally toward the development of coarse forage grasses which will readily withstand continuous

cutting. Such grasses are needed in Hawaii, where there is no cessation in the growing period. In an effort to help the farmer solve his immediate problems, the agronomist conducted thoroughly planned cooperative experiments on individual farms, where, among other things, crops forming the basis of the dairy and poultry industries were tested. In March, 1923, the agronomist left the station for a four months' trip to the Orient, where he will make a study of general-farming and poultry-raising methods applicable to Hawaiian conditions.

Work in the chemical division was devoted to the solution of problems arising in connection with the development of the starch industry and the preservation of various fruits and fruit products. Tests are being continued to determine the effect of soil, locality, and climate on the mineral constituents of Hawaiian-grown vegetables, and the effect of brackish irrigation water on certain crops growing on sand, loam, and clay soils. Fertilizer experiments with bananas and fertility-rotation experiments with pineapples and upland sugar cane are also being carried on.

In addition to traveling over 11,000 miles to visit and assist homesteaders, poultrymen, plantation managers, and ranchers, the extension agent for the island of Hawaii gave much of his time and attention to directing the work of the cooperative experiment station at Glenwood, cooperative work on the Parker ranch, Kamuela, to the fruit-tree nursery near Hilo, and to garden and club work in the schools. The general-extension activities of the central station extended to all the outlying islands, and included many kinds of service.

The station continues to maintain two substations, one at Glenwood, Hawaii, and the other at Haleakala, Maui. The former is operated as a well-balanced stock farm with dairy cattle predominating. Data obtained in experiments carried on at this farm are passed along by the extension agent to farmers similarly situated throughout the islands. At the Haleakala substation and demonstration farm investigations were made to determine the cultural requirements and adaptability of a large number of crops to the somewhat unfavorable climatic conditions prevailing on the slopes of the Haleakala volcano.

In the division of home-demonstration activities very pleasant relationships were established with various Territorial institutions and manufacturing concerns, and large groups of women, representing many nationalities, were reached by the collaborator in charge.

Under the direction of a club leader, boys' and girls' club work is being conducted in cooperation with the University of Hawaii, the Star-Bulletin Garden Contest Association, the Young Women's Christian Association, the Salvation Army Boys' Home, and the public schools.

At the central station a number of the buildings were repainted and several of the roofs were retreated with graphite paint to protect the shingles. Two cesspools were dug to improve the sanitary condition of the station dwellings. A thief-proof fence was built around the various experimental plats, and a start made toward fencing the experimental plats at the Tantalus substation.

During the year the following publications were issued by the station: Annual Report for 1921; Bulletin 48, Swine Raising in Hawaii, by F. G. Krauss; Bulletin 49, The Acid Fruit Lime in Hawaii, by W. T. Pope; and Bulletin 50, The Sweet Potato in Hawaii, by H. L. Chung.

REPORT OF THE HORTICULTURAL DIVISION.

By W. T. Pope.

AVOCADOS.

Studies were made of the growth of trees, habits of productivity, and quality of fruit of about 90 varieties of avocados. Many of the promising sorts were described and photographed for future record, and propagating wood of the better varieties was obtained for experimental work. The winter avocado is especially promising, since apparently it can be made to bear and ripen its fruit during the months of the year when the ordinary summer avocado is not in season. The fruit has a high food value, containing approximately 18 per cent of fat.

The nonbearing habit of certain avocado trees is now one of the most vital problems confronting growers. This trouble is similar to that reported from Florida and California, where a rather extensive study showed that the nonbearing condition is due to a failure in pollination. It is concluded from a study of the flower in relation to methods of pollination, begun at the station during the last blossoming season, that cross-pollination is necessary, at least with certain varieties, to assure satisfactory crop production, and the interplanting of varieties is recommended. Pollination experiments will be continued with the next blossoming season.

In most instances Hawaiian soil conditions are such that it is impracticable to raise budded or grafted avocado trees in nursery rows prior to transplanting them elsewhere. Growing trees in flowerpots, tin cans, and wooden boxes is an unsatisfactory method, owing to the complications which arise before the trees attain sufficient size and strength to permit of their being transplanted to the open. Although budding has been considered the best method of propagating varieties of avocado, budded trees invariably fail to make satisfactory growth. At the station an improved method of grafting very young seedling avocados is followed, using as scions the tender terminal shoots of desirable varieties. It is thought that this method will greatly reduce the time required to get young grafted trees in condition for transplanting.

In connection with propagation work, a study of avocado rootstocks was made during the year. Although local propagators prefer Guatemalan seedling rootstocks to either the West Indian or the Mexican rootstock in propagating varieties of Guatemalan avocados, results obtained from rather extensive experiments made at this station would seem to indicate that the Guatemalan is not superior to the West Indian rootstock, particularly when the seeds used in growing the stocks have come from fruit of good quality. These in-

vestigations also confirm results of studies in other parts of the world with asexual methods of propagation. Due to the similarity of their natures, both the Guatemalan and the West Indian types may be united by budding and grafting. Further investigation may show a definite advantage of some one combination over another.

MANGOES.

Several new varieties of mango trees, having fine qualities of productivity and flavor of fruit and showing immunity to attacks of the Mediterranean fruit fly, were added to the station collection during the year. Continued wet weather favored the development of a fungus disease (due to *Glœosporium mangiferæ*) at the time many of the trees were in blossom, and as a result a number of the flowers dropped and young foliage and fruit in various stages of development became splotched with black. Sprayings with Bordeaux mixture and lime-sulphur were ineffective, owing to the frequency of showers. Only part of the crop was destroyed, however, and trees blossoming later are now bearing their full crop of fruit. Mango trees in nearly all parts of the Territory showed great resistance to wind in a severe three-day wind and rain storm occurring in January, 1923, the branches remaining unbroken.

Some of the seedling mango trees of Victoria No. 9 are attracting considerable attention by producing fruit identical with that of the parent tree (Mango No. 9). The seeds of the latter are polyembryonic, which it is thought gives one seedling as the result of cross-pollination and several vegetative (parthenogenic) forms producing fruit very closely resembling that of the original parent tree.

Attempts to graft young seedling trees with scions of desirable varieties by a modified form of the side tongue-graft method were 96 per cent successful. This method is an improvement of 46 per cent over the other methods hitherto used most successfully.

BREADFRUIT.

In an experiment undertaken to develop plants from root cuttings of the seedless breadfruit tree, 400 young trees were produced from 600 five-inch cuttings taken from the surface roots. This very nutritious and wholesome fruit has practically ceased to be used in the Territory, mainly because of the difficulty with which the tree is propagated.

BANANAS.

Thirty-five different varieties of bananas are being grown at the station, and studies are being made to determine the best varieties of the so-called cooking bananas. Kona Maimaoli appears to be the best. This variety has a fine flavor, produces bunches weighing from 90 to 100 pounds, and is undoubtedly the finest of the varieties for shipping. The plants do not withstand much wind, but they do exceptionally well in the Kona district, where conditions seem to be the most favorable to growth. Varieties suitable for use as fresh fruit include the Chinese, Brazilian, and Bluefields, only the first of which is as yet grown extensively enough for shipping.

PAPAYAS.

The results of the papaya investigations continue to be encouraging. The plant responds quickly to favorable conditions. Several varieties, imported from other parts of the world, have as yet shown little difference from the varieties already grown. Two of the leading sorts, Station Accession No. 4618, a long variety, and Station Accession No. 4617, a round variety, continue to produce fruit of high flavor and flesh which remains firm during the cool wet months of January and February when other kinds are inferior in quality.

CITRUS FRUITS.

Experiments are being carried on with oranges, limes, lemons, pomelos, shaddocks, and citron, and budded trees of the Hawaiian (Polynesian) orange are being propagated from the best selected trees of the Kona district where citrus trees do well. The cooperative experimental work, covering two 1-acre plats and directed toward the standardization of this excellent variety, is making very fine progress. About 400 budded trees have been distributed to cooperative growers throughout the Territory. The orchard at the central station contains miscellaneous varieties of many kinds of citrus, all of which are doing well. Cowpeas, intercropped with citrus, made the most efficient green-manure crop of the several kinds under trial during the winter months.

GRAPES.

Trial plantings of the famous currant grapes of Greece are being made on the semiarid steep hill and mountain sides to determine the possibility of establishing a currant industry in Hawaii. The station has a number of varieties under test, including the Isabella, Concord, Tokay, Cornichon, Thompson's Seedless, Almeria, Zante, Malaga, fox, muscadine, Niagara, Scuppernong, Golden Queen, and a tropical grape (*Vitis tiliæfolia*). Isabella, a very prolific variety and well adapted to island conditions, may be made to ripen its fruit every month of the year. New varieties possessing desirable qualities are being grafted on Isabella rootstocks, and experiments are being made to determine the effect of pruning at different seasons on time of fruiting. Several thousand rooted plants were distributed during the year.

TOMATOES.

Tomato investigations are of importance in that they have for their object the production of varieties that will resist attacks of the Mediterranean fruit fly. So far, very few of the progeny from cross-pollinations have closely approached the ideal type. In progress is another experiment in which are being grown many desirable types having habits as well as characters to be combined, it is hoped, in the new and more substantial type.

NUTS.

The nut investigations of the year were confined to five species, the Macadamia, pistachio, walnut, almond, and cashew, and as yet have resulted in little more than making these nuts known to growers. Nut culture has excellent possibilities in Hawaii.

INTRODUCTION AND DISTRIBUTION OF NEW AND IMPROVED PLANTS.

Approximately 150 new varieties of plants were received by the station from the Bureau of Plant Industry, United States Department of Agriculture, and from interested persons living in various parts of the world. Many of these plants are of economic value in their native land and already give indications of being of value in Hawaii.

In addition to distributing a large number of thoroughly tested plants to interested growers throughout the Territory, the horticultural division also supplied limited quantities of new plant material, which had not been fully tried out by the station, to especially selected cooperative growers who are willing to assist in determining the value of new plants in various parts of the Territory.

REPORT OF THE AGRONOMY DIVISION.

By H. L. Chung.

Severe rain and wind storms occurring in the middle of January so severely damaged newly planted experimental plats as to necessitate replanting many of them. Root crops escaped more or less, and a large part of the corn matured sufficiently for harvesting.

GRASSES.

Napier grass (*Pennisetum purpureum*) is demonstrating its value as a forage crop for dairy cattle by rapidly putting out vigorous growth after a crop is cut for green feed. Many thousands of cuttings have been furnished to local dairymen for propagating purposes.

Guatemala grass (*Tripsacum laxum*) this year bloomed for the first time since it was planted, in August, 1919.

UBA CANE.

During the year Uba, or Japanese, cane tasseled. It has been extremely difficult to get this cane to flower, and when tasseling did occur, the station, working in cooperation with the Hawaiian Sugar Planters' Association, hybridized the variety with pollen from the best sugar cane varieties available for the production of a superior progeny. The hybrids are under observation and will be thoroughly tested to determine their sugar-producing possibilities and their adaptability to local conditions, especially with regard to ability to resist disease.

SWEET POTATOES.

During the year a test was made to determine the comparative yields, quality, and ability to resist fungus and insect attack, of 34 native varieties of sweet potatoes from Kauai and Maui and 37 varieties from the mainland. All but 5 of the imported sorts were grown for the first time at this station. Comparison of the native varieties with those grown at the station has shown the latter to be true to name as originally given by the native Hawaiians. The following table gives the comparative yields of native and imported varieties:

Comparative yields of locally grown and imported varieties of sweet potatoes.

Station No.	Locally grown varieties.	Calculated yield per acre.	Station No.	Imported varieties.	Calculated yield per acre.
		Tons.			Tons.
1596	Mohihi	2.04	1563	Yellow Jersey	2.22
1597	Manana	8.17	1564	Big Stem Jersey	3.74
1598	Mahina	4.88	1568	Big Leaf Improved	3.97
1599	Pu	4.22	1550	Big Leaf	3.06
1600	Manuia	2.89	1553	Early Carolina	3.28
1601	Kiikiki	2.38	1549	Waite's Improved Big Stem	1.02
1602	Mohihi	2.83	1571	Early Carolina	2.22
1603	Mauaniana	2.38	1578	do	2.22
1604	Naleimaile	2.22	1556	Porto Rican	3.51
1605	Pikolehua	2.49	1562	Triumph	6.01
1606	Kauai	1.70	1548	Dixie Yam	5.33
1607	Koloa 1	1.87	1551	Old Long Red	1.70
1608	Koloa 2	7.26	1547	Jewel Yam	1.59
1609	Koloa 3	4.25	1554	Belmont	2.15
3844	New Era	5.96	1555	New Gem	3.17
1611	Kapaa	3.85	1570	Creola	2.04
3842	Madeira	2.25	1575	Vineless	1.93
3838	Delicious Yellow	0.73	1574	General Grant Vineless	5.56
3874	Tantalus	2.69	1566	Japanese Brown	3.40
98A	Seedling	3.17	1582	Myers' Early	3.88
3871	Yellow Yam	2.94	1572	Pumpkin Yam	3.88
88A	Seedling	2.89	1573	Pierson	5.96
114C	do	4.93	1519	Yellow Yam	3.74
3856	do	2.95	1559	Southern Queen	1.93
111A	do	2.65	1569	Miles' Yam	1.93
3856	Puukeokeo	2.89	1576	Norton Yam	2.61
3845		3.74	1581	Shorthorn	4.42
39		3.40	1584	Enormous	6.24
1324		3.57	1577	Pumpkin Yam	2.95
3851	Kikola	2.89	1583	Yellow Strasburg	5.10
1345	Berlina	4.09	1561	Nancy Hall	1.81
56		2.38	1560	do	2.49
439		2.20	1580	Red Bermuda	6.35
3840	Laupahoehoe	2.38	1565	Japanese Brown	1.36
			1567	Red Jersey	3.74
			1591	Porto Rican	5.07
			1592	Triumph	4.53

MANGEL WURZELS.

The varieties Giant Yellow Intermediate, Long Red, Yellow Globe, and Golden Tankard, obtained from England for trial as a winter crop, were planted September 8, 1922, and harvested March 8, 1923, yielding approximately 2.58, 1.35, 1.46, and 3.31 tons, respectively, per acre. Giant Yellow Intermediate and Golden Tankard made the heaviest yields and continued to grow when the other two varieties appeared to be in a dormant condition.

SUNN HEMP.

Sunn hemp (*Crotalaria juncea*) continues to give great promise as a green manuring crop, especially in connection with wornout pineapple lands. In culture tests made during the year, seed was produced at the rate of 1,038 pounds per acre. Requests for seed came from the mainland as well as from local homesteaders and pineapple growers. Selection work for improvement in foliage and seed is under way, it being the desire of the station to develop leguminous green-manure crops which will not only make efficient cover crops and produce seed, but will also quickly produce an abundance of green manure for plowing under for soil-improvement purposes. Sunn hemp and pigeon peas are the most promising of the various green-manure crops now under test.

DISTRIBUTION OF SEEDS AND CUTTINGS.

The production of seeds and cuttings early in the last fiscal year enabled the station to meet the unusually heavy demands of the present year. A large part of the distributions were made to schools for school-garden work. In addition to 510 corms or tubers of edible canna, distribution from July 1, 1922, to June 30, 1923, was made in amounts as follows:

Seeds and cuttings distributed during the fiscal year ending June 30, 1923.

Crop.	Cuttings.	Seed.	Crop.	Cuttings.	Seed.
	Number.	*Pounds.*		*Number.*	*Pounds.*
Guam corn		211	Napier grass	47,434	
African sorghum		8	Merker grass	10,408	
Yam beans		3	Pigeon peas		54
Hybrid cowpeas		130	Alfalfa		25
Velvet beans		7	Crotalaria		70
Clover		3	Beans (all varieties)		158
Peanuts		33	Bermuda grass	2,746	
Uba cane	3,446		Sweet potatoes	7,601	

POULTRY.

The poultry work was carried on along essentially the same lines as last year. Considerable time was devoted to demonstration work in flock improvement and the treatment of disease. The poultry department of the University of Hawaii was assisted in conducting its first egg-laying contest, and each contesting hen was examined for characteristics indicating egg-laying capacity. Local poultrymen were materially aided in obtaining desirable breeding and laying stock, over 5,000 such fowls being imported between November, 1922, and February, 1923. Poultry raising is being carried on on a rather extensive scale on Maui. The district of Makawao is ideal for poultry raising. Homesteaders on this island were assisted in drawing plans for poultry houses and in overcoming problems connected with poultry management.

REPORT OF THE CHEMICAL DIVISION.

By J. C. RIPPERTON.

BANANAS.

Fertilizer experiments with the Chinese banana have almost without exception given negative results in past years. That some form of fertilizer is needed, however, is proved by the stunted appearance of the plants and the growing of the fruit in small bunches in many fields. Climatic factors are not the cause, since certain fields in a given locality produce excellent bananas, while others closely adjacent and given similar treatment yield very inferior fruit. As a result of rather elaborately planned fertilizer experiments carefully carried out during recent years by the station and individual growers, as well as of observations of the nature and feeding habits of the plant, it is concluded that in certain sec-

tions the banana is prevented by adverse soil conditions from utilizing the plant food applied. Results of analyses of the seepage water at the lower boundary of a fertilized field to determine the effect of heavy applications of irrigation water on leaching of the readily soluble fertilizer from the feeding zone of the plants, showed a very appreciable leaching of all the fertilizer elements. Accordingly, an experiment was begun to determine the best method of applying fertilizer to the crop. The same quantity of a complete, ready-mixed commercial fertilizer was applied to each plat, and four different methods of application were used. In the first test the total quantity was applied at one time about the base of the plant; in the second test the total quantity was placed in the sides of the furrow and about the level reached by the water during irrigation; in the third test the total quantity was given in six monthly applications about the base of the plant immediately before irrigation; and in the fourth test the total quantity was given in six monthly applications about the base of the plant immediately after irrigation. The first crop of the experiment has been harvested and fertilization of the second crop completed. It is expected to carry this experiment through two more crops.

Pot and field experiments are to be conducted to permit a study of the general feeding habits of the banana, its susceptibility to various soil toxins, and the physical properties of the soil affecting growth.

FERTILITY-ROTATION EXPERIMENTS WITH PINEAPPLES, UPLAND SUGAR CANE, AND PIGEON PEAS.

This experiment was undertaken to determine the feasibility of providing rotations for pineapples and sugar cane and at the same time preventing the usual soil depletion accompanying the single-crop system by growing pigeon peas as a green-manuring crop. The decrease in yields with continuous cropping to pineapples is very manifest in Hawaii. A fertilizer experiment is being carried on in conjunction with the rotation experiment. The experiment has been carried through two crops each of pineapples and sugar cane, and the pigeon pea crops have been alternately plowed under and removed. The pineapple and sugar-cane areas are being plowed at the end of the second crop harvest, and the second step in the rotation will be begun this fall (1923) when the pineapple plat will be planted to sugar cane, the sugar-cane area to pigeon peas, and the pigeon pea area to pineapples.

HAWAIIAN STARCHES.

Investigations were continued with various tropical starches to determine the more scientific phases attending their commercial development.

Tree fern.—Experiments with the tree fern for the production of starch were concluded. It has been found that, relative to replanting cut-over areas, an average of three young tree ferns can be obtained from each felled mature tree fern. The rate of growth of this genus is, however, too slow to make it commercially practicable to replant the tree fern for its starch content.

Edible canna.—Preliminary investigations on certain phases of the culture of edible canna and the properties of its starch were completed, and the following conclusions drawn: The chemical composition of a hill of edible canna is fairly constant, regardless of its age. Although there is considerable difference between the mature and the immature type of tubers, the hill as a whole remains practically constant. The feeding value of the edible canna, both tubers and tops, is about the same as that of the other common tuberous and nonleguminous forage crops. Canna starch is characterized by its unusually large granules, and its properties are similar to potato starch. It is thought to have possibilities as an industrial starch.

Edible canna investigations are being continued. A fertilizer experiment has been begun to learn the best method of applying fertilizer to the crop, and another has been planned to ascertain the fertilizer formulas best adapted to it. Cooperative investigations have been undertaken with a local starch company to solve the problems incident to the manufacture of the starch and the utilization of the by-products.

JELLY MAKING FROM TROPICAL FRUITS.

In an attempt to introduce into commercial jelly making in Hawaii more scientific methods than are now used, the chemical division conducted experiments with fruit juices for pectin and acid, determined the proper sugar ratios, and made a study of the resulting products.[1] Much of this work has been carried on in cooperation with a local jelly company.

Preliminary work has been started to determine the feasibility of using commercial pectin in making certain tropical jelly and jam products. Various formulas for its use are being developed, and studies made of the relative cost and palatability of the resultant products. Work of a more fundamental nature is being undertaken to determine the physical differences in the pectins of different fruits, the relative "gelling strength" of each pectin, and the character of the gel produced.

EFFECT OF CLIMATE AND SOIL ON THE COMPOSITION OF HAWAIIAN VEGETABLES.

The opinion prevalent among certain classes in Hawaii that locally grown vegetables are lacking in certain essential mineral constituents is not without scientific foundation. Shorey[2] found the forage crops of the island deficient in lime, and Johnson[3] showed that pineapples are unable to assimilate iron from certain soils. As a result of this opinion, locally grown vegetables are discriminated against in favor of canned products from the mainland. Preliminary analyses of a series of spinach samples grown on the mainland and in Hawaii, indicated that generally this vegetable is richer in mineral constituents than is the mainland spinach. In a rather extended experiment, planned to determine the effect of tropical climate and volcanic soil on the composition of vegetables, two leaf vegetables (spinach and cabbage), two root vegetables (carrots and

[1] Hawaii Sta. Bul. 47, Applications of the principles of jelly making to Hawaiian fruits, by J. C. Ripperton.

[2] Hawaii Sta. Bul. 13, The composition of some Hawaiian feeding stuffs, by E. C. Shorey.

[3] Hawaii Sta. Press Bul. 51, The spraying of yellow pineapple plants on manganese soils with iron sulphate solutions, by M. O. Johnson.

beets), and two pod vegetables (peas and beans), were selected for study. Seed was obtained from a reputable firm and planted in two widely separated areas on the mainland (Virginia and Washington), and likewise in two localities on Oahu. The vegetables from each place were dehydrated and together with a sample of the soil in which they were grown were sent to this station for analyses. Both vegetables and soils are now being analyzed.

SALT TOLERANCE OF VARIOUS PLANTS GROWN IN SAND, LOAM, AND CLAY SOILS.

Extensive investigations were made to determine the tolerance of various crops to brackish irrigation water and with soils derived from igneous and metamorphic rock and under Temperate Zone conditions. Data on the tolerance to sodium chlorid of various crops grown on volcanic soils and under tropical conditions are rather fragmentary; and likewise, both the nature and extent of the physical and chemical effects of this salt on volcanic soils are unknown. The investigations included lysimeter, laboratory, and field experiments.

Lysimeter experiments.—Typical soils of Hawaii were placed in lysimeters and planted to alfalfa (Pl. I, fig. 1), Napier grass, rice, sugar cane, and carrots. The effect of varying concentrations of sodium chlorid in the irrigation water upon the growth of the several crops was studied and the leachings from the lysimeters were collected and analyzed. (Pl. I, fig. 2.) These studies will be carried through two or three crops to determine the cumulative effect of the salt upon the soil.

Laboratory experiments.—Studies were made of the physical and chemical changes taking place in the soils used in the lysimeter experiments, and also of soils taken from various districts which have been irrigated with brackish irrigation water for many years. Field observations and laboratory tests thus far conducted indicate that these changes are very appreciable and eventually will become a serious menace to the productivity of the soil.

Field experiments.—The salt content of both water and soil was determined in the important districts using brackish irrigation water, and the character of the crops and condition of the soil were noted. During the year two crops were grown in the lysimeters. Methods were devised for ascertaining the physical changes taking place in these soils. The irrigation water used on the islands of Kauai, Hawaii, and Oahu was tested and soil samples collected for further study.

REPORT OF EXTENSION AND DEMONSTRATION WORK ON THE ISLAND OF HAWAII.

By R. A. Goff.

GLENWOOD SUBSTATION AND DEMONSTRATION FARM.

F. X. Helbush, the collaborator in charge of the Glenwood substation and demonstration farm, is making every effort to maintain this farm as a self-supporting unit. During the year the dairy herd increased to 31 head, 7 of which are young females. A registered

Holstein bull now heads the herd. Eight heifers will come in this year, bringing the milking herd up to 15. Three old Berkshire sows and two of the best of their litters are being kept. The purebred White Leghorn poultry flock increased from 300 to 475 laying hens. It is planned to increase this flock to 800 laying hens this year and to 1,000 the year following, and during these two years to bring up the dairy herd to 20 milking cows. Napier grass and pigeon peas are being grown to help feed the animals. The eggs, cockerels, butter, calves, and hogs will be marketed locally. Muscovy and Pekin ducks were purchased as foundation stock for the production of progeny for experimental purposes.

Farm buildings for the animals were altered and enlarged during the year. A 40-foot extension was added to the cow stable, an iron-roof shed was erected for the hogs, an iron-roof awning was placed in front of the barn, and a new fence was built around the 30-acre pasture lot. New roofs were put on the poultry houses, and the yards were rearranged to permit of larger runs. A dwelling for a laborer who also acts as night watchman was erected near the poultry houses, and a water tank having a 10,000-gallon capacity was built. Two others of the same size were purchased and will be put up this year.

WORK AT THE KAMUELA COOPERATIVE EXPERIMENT STATION.

The Kamuela Experiment Station is operated by the Parker ranch. The area in pasture grasses and field and forage crops was enlarged during the year, and such crops as Russian brome, redtop, Harding grass, Peruvian winter grass, *Paspalum larranagai*, *P. notatum*, *Phalaris bulbosa*, Australian tall fescue, purple vetch, alfalfa, and sweet clover, which looked promising at the end of the first year, were planted in one-third acre plats. Selected seed of corn grown last year is being planted in six areas totaling 2 acres. Seed of 16 kinds of range grass, obtained through the Montana Experiment Station from varying altitudes and from wet and dry localities in Montana, will be planted in small plats to test their adaptability to conditions prevailing in the ranching districts of Hawaii. Seeds, cuttings, and roots of crops growing well at the station were distributed to homesteaders in the Kamuela district and to dairymen and ranchmen in Kona, Kau, and near Hilo.

GENERAL ACTIVITIES OF THE EXTENSION AGENT.

Talks to school children and homesteaders.—Talks on gardening and garden crops were given to school children at morning assembly: spraying and proper methods of cultivation demonstrations were conducted; and discussions were given on seed varieties and depth of planting. Illustrated lectures on butter making, pruning, and budding, as well as discussions of crops best suited to the different localities, poultry, dairying, and hog raising, were given assembled groups of homesteaders in the various districts.

Boys' club work.—Each interested child of the island schools having a sixth or higher grade, was given a quantity of corn and seed potatoes sufficient to plant a minimum of 1,000 square feet. Bulletins on corn and potato growing were distributed to the young gardeners, and arrangements were made with a local poultryman to

FIG. I.—METHOD OF DETERMINING SALT TOLERANCE OF ALFALFA.

FIG. 2.—GENERAL VIEW OF LYSIMETERS IN SALT TOLERANCE EXPERIMENTS.

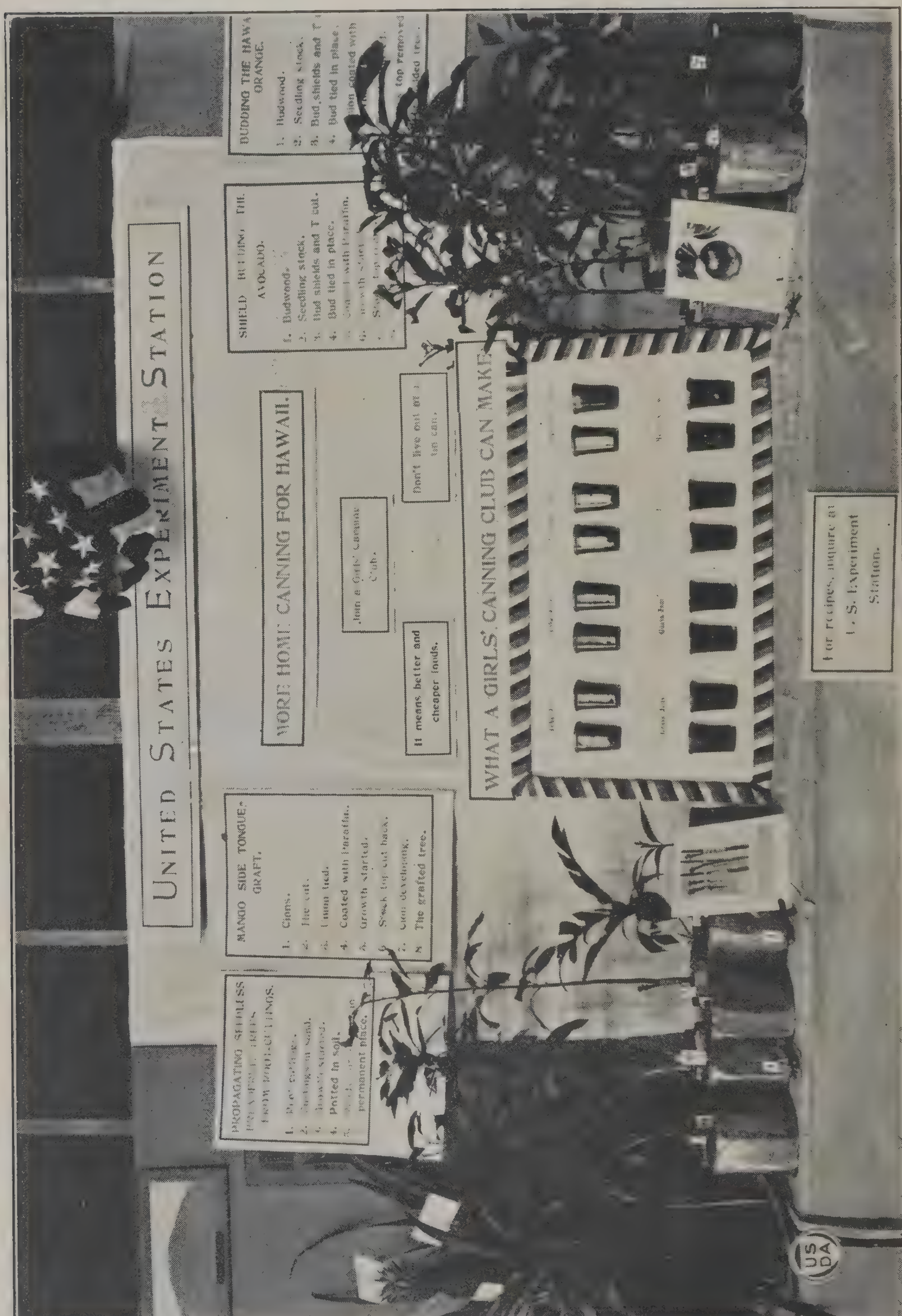

EXHIBIT OF HAWAII STATION EXTENSION DIVISION AT AGRICULTURAL FAIR.

supply a setting of eggs to each boy interested in poultry work. Chickens were hatched and raised to 3 months of age, at which time they were exhibited at the county school fair and the poultryman was given his choice of one pullet to pay for each setting of eggs. Farmers' Bulletins on feeding and raising chicks were distributed to the boys and visits made to their homes, where assistance in making chicken coops and runs was given. Various problems were discussed at monthly meetings.

School and home-garden work.—Thirty schools entered the school-garden contest during the year with gardens ranging from one-fourth of an acre to 3 acres. Seed of corn, potatoes, alfalfa, pigeon peas, and sweet clover, together with instructions regarding each crop, were given to the children of 12 of the schools. Several times during the year the schools were visited and the extension agent acted as one of the judges in the different districts at the close of the contest. The island was divided into two main districts in the home-garden contest, which made it possible to have the children of each garden compete with those of the same grade in each of the two districts.

Hawaii school fair.—The best products from the gardens of the whole country were displayed in the agricultural section of the Hawaii school fair. Fully 4,000 children visited the fair. Pupils and teachers obtained the names of varieties of seed doing well in schools other than their own for the purpose of planting the most successful kinds in the future. The extension agent acted as chairman of the agricultural committee, and entry lists were made out, interest in entries was aroused in the different schools, judges were secured, exhibits displayed, and awards sent to the winners.

Seed distribution.—Owing to difficulty in obtaining sufficient feed for cows, pigs, and poultry, especially in the sugar-cane districts, where large areas are devoted to cane growing, the extension agent persuaded homesteaders in each district to prepare a plat for various field crops and distributed seed of corn, alfalfa, and sweet clover, and cuttings of Merker grass, Napier grass, and Uba cane. Sweet potato cuttings and vegetable seeds of varieties suited to the different localities were also distributed. The seed of the Solo papaya, which is a good table variety, and of a larger growing papaya for use as a hog feed, was given to those requesting it.

Distribution of literature.—United States Department of Agriculture Farmers' Bulletins and bulletins published by the station on vegetable gardens, field and forage crops, livestock, and farm buildings were distributed during the year. Extra copies of seed-house catalogues were obtained for those requesting them, and newspaper articles dealing with agricultural topics of especial interest were loaned to various farmers.

Assistance in marketing.—Samples of products grown in the Kamuela and Kona districts were taken to dealers in Hilo, and arrangements made for future shipments. Demonstrations were given producers in proper methods of sorting and grading, and suitable containers were obtained for them. Dealers who have been purchasing a large supply of potatoes, poultry, and dairy supplies from the mainland cooperated in marketing the local produce. The extension agent also assisted in marketing sweet corn, rhubarb, and avocados.

Assistance in boy scout activities.—The extension agent continued to act as scout commissioner for the island and as examiner for boy scouts competing for the agricultural merit badge.

Fruit tree nursery.—Buds from grapefruit and navel and Kona orange trees were grafted on 300 wild-lemon seedlings, and more than 500 avocado seedlings were worked over into winter-bearing trees. Many of them were distributed to different parts of the country and withstood transplanting without injury. About 800 citrus seedlings are now ready for budding and as many avocado seeds are being planted for the coming year.

Spraying demonstrations.—In the Kohala and Hamakua districts, where growers experience difficulty in keeping pineapple plants in a healthy growing condition, due to lack of available necessary plant food in the soil, demonstrations of the proper methods of treating the soil were conducted. Demonstrations were also given of the preparation and application of Bordeaux mixture as a control measure for potato blight occurring in the Hamakua, Kamuela, and Kona districts; as well as of poison bait for cutworms, and Paris green and arsenical mixtures for garden pests occurring in the volcano district near Hilo.

Assistance in planting windbreaks.—Seed and seedlings of eucalyptus, black wattle, Monterey cypress, and ironwood trees were distributed in the Kau, Kohala, and Kamuela districts.

Miscellaneous activities.—Active assistance was given farmers in bringing in from the mainland at least 5,000 laying hens. Assistance was also given in culling the fowls in an egg-laying contest conducted by the University of Hawaii. Demonstrations of the proper methods of utilizing locally grown fruits and vegetables were carried on in cooperation with various Territorial agencies which are interested in nutritional work with underweight children. In an effort to cultivate a liking by the people for milk and butter as well as for home grown fruits and vegetables demonstrations were also given setting forth the value of fresh, locally produced food products. At some of these meetings the members of the extension division came in contact with parents as many as 520 times during a single month.

HALEAKALA SUBSTATION AND DEMONSTRATION FARM.

By H. F. Willey, *Superintendent.*[4]

At the Haleakala substation and demonstration farm, where normally the rainfalls are light and the winds high, unusually heavy torrential storms occurred during the year. Several rows of *Eucalyptus robusta* were successfully established as windbreaks along the windward side of the farm, and Napier grass and Uba cane were set as secondary windbreaks at intervals across the farm rows. A road was constructed across the gulch dividing the farm unit into two sections, and the roadway leading from the main road to the residence and farm buildings was improved. The field as a whole was given deeper tillage than formerly, and, as a result, the crops are responding satisfactorily. Approximately 194 varieties of 74

[4] Temporarily employed.

crops were planted, including pineapples, pigeon peas, field corn, sweet corn, pop corn, tomatoes, and sweet potatoes. Fully 600 visitors to the farm inspected the various plantings.

In addition to assisting with school-garden activities and the Maui County Agricultural Fair held in October, 1922, the superintendent gave suggestions to homesteaders relative to improved methods of planting and tillage, selected and ordered seed for homesteaders, and obtained prices on fence material and purebred stock for them.

REPORT OF HOME DEMONSTRATION ACTIVITIES.

By Mrs. Nellie A. Russell.

The home-economics demonstrator again instructed groups of Japanese, Chinese, Philippine, Portuguese, and Hawaiian women in the art of home making in harmony with American ideals. These women are anxious to learn methods that are an improvement over those to which they have been accustomed, especially in regard to the utilization of local fruits and vegetables. A large number of the demonstrations were given with the assistance of interpreters to groups of working mothers during the noon hour. Rooms were provided for the occasion by the various business concerns which have become interested in this phase of Americanization work among the several nationalities. Special instruction and demonstrations in cooking and serving meals, as well as lessons in dressmaking and millinery, were given to older girls. The sewing classes require a great deal of individual attention, since the teaching of sewing does not lend itself readily to group presentation.

BOYS' AND GIRLS' CLUB WORK.

By Mabel Greene.

As soon as the club leader arrived in Hawaii in April, 1923, efforts were made to have the boys' and girls' club work correlated with the work of the public schools under the direction of teachers who are trained in agriculture and home economics. The public schools, beginning with the fifth grade, have a very definite place in their curricula for these studies. Club members are also receiving instruction in how to keep records, conduct business meetings, and assist in public demonstration work. The latter activity has a far-reaching influence upon the older people in each neighborhood. During the year club work was organized in three districts in Honolulu. Canning, dairy, garden, rabbit, poultry, home-management, and sewing clubs were organized, with an enrollment of 110 members. Considerable time was spent in studying local conditions and in establishing pleasant cooperative relationships for conducting the work. The garden club work embraces 46 members at the Salvation Army Boys' Home, where a new tract of land has been made available. Agricultural slides, furnished by the United States Department of Agriculture, were shown at the various meetings by

means of a stereopticon; and corn, beans, and peanut seed, together with young papaya trees and sweet potato cuttings, were distributed to members. Demonstrations of the best methods of planting were given at the time the distribution was made.

A group of girls, ranging in age from 16 to 18 years, are studying home-management problems in coopertaion with the club department of the Young Women's Christian Association. They have already learned how to use the fireless cooker and are planning to make one for their club rooms, which they are furnishing. These girls have completed a luncheon set and expect to learn canning work during the July and August meetings.

The school fair in Honolulu, May 25 and 26, 1923, afforded an excellent opportunity for parents and others interested to view the agricultural and home-economics work being done in Maui, Hawaii, and Oahu by the boys and girls. The extension agent served as a judge of the cooking contest held May 26. Club work will be closely affiliated with contest work, but separate club records will be kept and public demonstrational work will receive increased emphasis. The exhibit of local food products of the central station was allotted space in the Territorial Normal School exhibit (Pl. II). The club leader will meet the teachers attending the summer session, June 25 to August 3, 1923, to tell them of the purpose of the boys' and girls' club work and explain to them how they can assist in furthering it.

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HAWAII AGRICULTURAL EXPERIMENT STATION
HONOLULU, HAWAII

Under the joint supervision of the
UNITED STATES DEPARTMENT OF AGRICULTURE
AND THE UNIVERSITY OF HAWAII

REPORT OF THE HAWAII AGRICULTURAL EXPERIMENT STATION

1934

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OFFICE OF EXPERIMENT STATIONS

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Washington, D. C. January 1935

REPORT OF THE HAWAII AGRICULTURAL EXPERIMENT STATION, 1934

CONTENTS

INTRODUCTION

The continued low prices of sugar and pineapples have resulted in an increase in attention given to the problem of the wisest utilization of the marginal and submarginal lands for the growth of other crops which are not at present being overproduced. The Territory is also faced with the problem of the best use of the acreage that will probably be taken out of production of the two leading crops—sugarcane and pineapples. While the sugar and pineapple producers maintain their own experiment stations primarily for working out the problems which arise in connection with their respective industries, they have been able to render valuable assistance in various cooperative activities looking to the further development of the minor agricultural industries throughout the islands.

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The development and application of an economical and rapid method of determining the fertilizer needs of diversified crops on various soil types, based on the Mitscherlich principle, has continued to constitute one of the outstanding projects of the station. Various crops, such as coffee, Macadamia nuts, potatoes, rice, soybeans, panicum (Para) grass, Sudan grass, Oriental kale, carrots, etc., have been studied by this method. Several improvements and additions to the equipment for use in the method were made during the year. The revolving type of table to hold the pots, as developed by the experiment station of the Hawaiian Sugar Planters' Association, was installed. An additional greenhouse was built. This is capable of carrying 14 revolving tables of 12 pots each (fig. 1).

FIGURE 1.—Mitscherlich pots mounted on revolving tables to secure maximum as well as uniform utilization of light. Each series of pots is placed on a separate revolving table. The tables are made to turn one revolution in about 10 minutes by means of an electric motor and a series of reduction gears. The tables are mounted on old automobile axles.

The Mitscherlich pot method offers especial promise under local conditions, as a means of studying plant nutrition and soil fertility, both from a fundamental as well as a practical standpoint. During the year a variety of crops was grown successfully in Mitscherlich pots, and it appears that nearly all of the ordinary root, tuber, leaf, or pod vegetable crops, as well as the various grasses, will grow normally (fig. 2).

A great advantage of being able to use various crops in supplementing a single indicator plant, like Sudan grass, is that the results are of immediate value without the necessity of first establishing the correlation between the indicator crop and the crop being studied. In addition, the growing of the crop itself in the pot test enables one to study specific problems of the crop not directly related to the available plant food.

Special technics are required for the successful growth of the various crops by the Mitscherlich pot method. For example, with potatoes, the whole tubers are pregerminated in coral sand until the developing stem has 2 or 3 small leaves. Uniform plants are then selected and the seed potato is cut away with a knife until about 15 grams of tissue remain. Three such plants are then transferred to each pot and allowed to grow to maturity. Frequent sprayings and dustings with bordeaux mixture, sulphur, and nicotine are required. With the succulent leaf crops, shading and humidifying with fine water spray are also necessary. With proper care, duplicates can be obtained with a difference no greater than 4 to 8 percent.

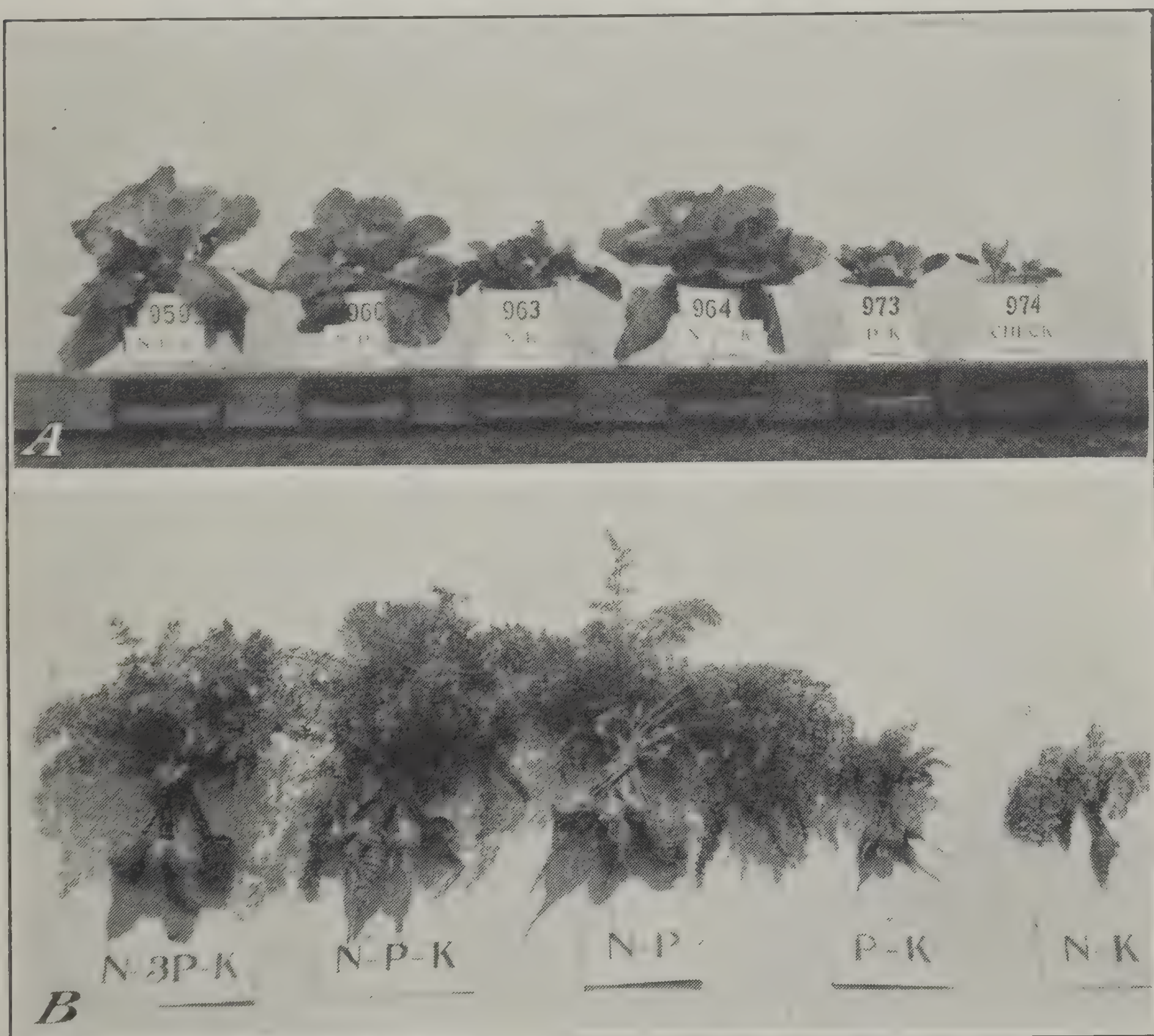

FIGURE 2.—*A*, Cabbage; *B*, carrots. A variety of vegetable crops can be grown in Mitscherlich pots. Response of these crops, in pots, to fertilizer gives promise of being a valuable indicator of field results.

With the realization that the results obtained at this stage of the work are often of qualitative value only, due to changes in technic which must inevitably result from further study, emphasis has been placed on technic rather than any attempt at close correlation with field results. Since every different crop grown in pots would require the development of a special technic, an attempt is being made to use one crop as an indicator for a group of closely related crops, the specific crop indicator being selected on the basis of hardiness, rapidity of growth, and response to fertilizer. For the leafy vegetables, Oriental kale (*Brassica oleracea acephala*) offers promise as

an indicator. It is hardy, not much attacked by insects, and grows rapidly. For the root crops, the red radish seems well adapted. It produces roots of large size in pots and grows rapidly. Preliminary tests with the various pod crops indicate that the bush beans grow better than the climbing varieties.

Continued search is being made for a general indicator crop to be used in place of Sudan grass. This grass has many desirable qualities as an indicator, chiefly uniform and rapid growth, ability to grow in very hot as well as cool weather conditions and very low experimental error among duplicates. In certain soils, however, it makes a very weak growth regardless of the fertilizer treatment. Another objection is its supersensitivity to phosphates. In many of the island soils the yield of the pot receiving nitrogen and potassium but no phosphorus is not more than 4 to 8 percent of that of pots receiving complete fertilizer (nitrogen, phosphorus, and potassium).[1] Much more exact measurement could be made of the differences between soils if a less phosphate-sensitive crop could be found. In this respect panicum (Para) grass (*Panicum purpurascens*) is being tried. For planting materials, one node with an inch section of stem is used. Ten of these are inserted into each pot without pregermination. If care is used in selection of planting material near to the vigorously growing tips, excellent growth and uniformity can be obtained. In poor soils it appears to make a more vigorous growth than Sudan grass. Tests are being made to determine how small an experimental error is possible.

Satisfactory progress was made in all of the 43 active projects of the station, although several other projects were placed on the inactive list owing to lack of adequate funds and personnel for their prosecution.

New lines of work undertaken included (1) life-history and growth-habit studies of certain grasses and legumes under tropical conditions, (2) studies as to the relative merits of various types of plantation back-yard poultry houses, (3) battery systems for laying and breeding hens, (4) artificial illumination for laying stock, (5) tree kale as a source of green feed for poultry, (6) vitamin transfer between certain plant tissues, and (7) chemical studies of the passion fruit.

Old lines of work completed or suspended included (1) the feeding of cane molasses to dairy cows, (2) sorehead control of baby chicks and poults, (3) sex determination of day-old purebred chicks, (4) value of taro and fermented poi in poultry-fattening rations, and (5) determination of the iodine content of Hawaiian sea foods.

Experiments were carried out by the agronomy division at various places throughout the Territory with range grasses, pigeonpeas, rice, green manures, forage, and vegetable crops.

The manuscript for a bulletin, giving the results of feeding cane molasses to dairy cows over a period of 8 years, was submitted for publication (see also p. 24). A bulletin showing the results of feeding cane molasses to swine was published (*4*).[2] An experimental

[1] In these and the fertilizer pot experiments referred to in other later places in this report, the nitrogen was, unless otherwise specified, supplied in the form of ammonium nitrate, phosphorus as sodium acid phosphate (monobasic), and potassium in the form of potassium sulphate.

[2] Italic numbers in parentheses refer to Literature Cited, p. 31.

dairy herd of 51 animals of all classes was maintained throughout the year, as well as a small herd of swine and a flock of poultry of sufficient size for the carrying out of approved experiments.

The chemical division of the station devoted its energies largely to the determination of the fertilizer requirements of the more promising minor crops (coffee, Macadamia nuts, rice, potatoes, etc.) and to the solution of technical problems arising in connection with such crops as the Macadamia nut. Special chemical investigations were also made of the iodine content of Hawaiian sea foods, as well as certain chemical constituents of avocados and passion fruit. (See also pp. 27, 28.)

In the horticultural division special attention was given to the development of an economic tropical aboretum, cultural and breeding studies of coffee varieties, akala berries, passion fruit, avocados, mangoes, etc. A bulletin on citrus in Hawaii (*6*) giving the results of 25 years' work was published, as well as a circular on the propagation of various trees, shrubs, and plants by cuttings (*7*).

The nutrition laboratory determined the nutritive constituents of numerous local fruits and made vitamin studies of certain important vegetables, fruits, and sea foods. A bulletin was published concerning Japanese foods commonly used in Hawaii (*5*).

The subject of poi manufacture and fermentation was studied by the division of bacteriology of the University of Hawaii, in collaboration with the station, and a bulletin on the subject was published by the station (*1*).

The poultry division developed the "live virus" method of sorehead control to a high degree of efficiency, and to a point where it was deemed advisable to turn the project over to a local commercial interest to furnish the vaccine to interested poultrymen throughout the islands. A station circular was issued on sorehead control. Caponizing also received attention and a circular on this subject was published (*2*). One Barred Plymouth Rock hen completed her laying year with a total of 313 eggs to her credit.

The soil physics division continued its studies of the water-holding peculiarities of Hawaiian soils.

The Haleakala substation (see also p. 30), on the Island of Maui, continued its experiments with range grasses at varying elevations, pigeonpeas, potatoes, and numerous other field crops and vegetables. The Kona substation (see also p. 31), on the Island of Hawaii, devoted its energies largely to the development of plantings of various species of coffee, avocados, mangoes, and numerous other fruits which possess promise under the local conditions. Selection work with Macadamia nuts and fertilizer experiments with coffee were also under way throughout the year. During the year an adjoining tract of 1.66 acres of arable land was acquired and is being planted to various introduced species of coffee for use in breeding work and variety tests.

The station budget for the year was $86,650, made up as follows: Territorial and university special funds, $24,000; Hatch fund, $15,000; Adams fund, $11,000; United States Department of Agriculture funds, $36,650. The last item was subsequently reduced by impoundments to the United States Treasury, which totaled $4,075. The budget for the previous year totaled $94,500.

PROJECTS

Research projects active during the year and their leaders were: Correlation between the magnitude of the sesquioxide ratio in an extracted soil colloid and soil-moisture availability (H. A. Wadsworth); breeding and selection of pigeonpeas, breeding and yield studies of forage crops, life-history and growth-habit studies of grasses and legumes under tropical conditions (C. P. Wilsie); relation of chemical composition of range grasses to pasture management (D. W. Edwards); varietal, cultural, and propagation studies of citrus, culture and breeding of Hawaiian raspberries (akala berry, *Rubus* sp.), and varietal, cultural, and propagation studies of Macadamia nuts (W. T. Pope); factors affecting chemical composition of Macadamia nuts (J. C. Ripperton); varietal, cultural, and propagation studies of coffee (W. T. Pope); rejuvenation of old coffee plantings, and nutrition and fertilizer studies of the coffee plant (J. C. Ripperton); variety tests and breeding studies of vegetable crops (C. P. Wilsie); cane molasses for dairy cows, sprouted oats for correcting breeding problems of dairy cows and brood sows, and sugar and molasses feeding of swine (L. A. Henke); control of sorehead of baby chicks and poults, sex determination of day-old purebred chicks, batteries for laying and breeding hens, artificial illumination for laying hens, gizzard-worm investigations (C. M. Bice); vitamin studies of Hawaiian foods and feeds, chemical and biological studies of protein in pigeonpeas, chemical and biological studies of the opihi (shellfish), studies of the transfer of vitamin B from rice bran to various types of plant tissues as a result of pickling them with salt and rice bran (C. D. Miller); and study of the sterol content and vitamin value of avocado oil, determination of the iodine content of Hawaiian foods, and chemical studies of Hawaiian plants, (1) poisonous plants, (2) passion fruit (L. N. Bilger).

PUBLICATIONS

The following is a list of publications of the station during the year covered by this report:

Report of the Hawaii Agricultural Experiment Station, 1933; Bulletin 68, Japanese Foods Commonly Used in Hawaii, by C. D. Miller; Bulletin 69, Cane Molasses as a Supplement to Fattening Rations for Swine, by L. A. Henke; Bulletin 70, The Manufacture of Poi from Taro in Hawaii: With Special Emphasis upon Its Fermentation, by O. N. Allen and E. K. Allen; Bulletin 71, Citrus Culture in Hawaii, by W. T. Pope; Circular 7, Capons and Caponizing, by C. M. Bice; Circular 8, Fowl Pox (Sorehead) Control by Vaccination, by C. M. Bice; and Circular 9, Propagation of Plants by Cuttings in Hawaii, by W. T. Pope.

Articles contributed by members of the station staff and published elsewhere than in the regular station series of bulletins and circulars included the following: The Nutritive Value of the Mountain Apple (*Eugenia malaccensis or Jambosa malaccensis*), by C. D. Miller, R. C. Robbins, and K. Haida (Philippine Jour. Sci. 53: 211–222. 1934); Local Crops High in Food Value, by C. D. Miller (Honolulu Star-Bull. Hawaii Farm Ann., Dec. 16, 1933, p. 50); An Inexpensive Water-Stage Register for Plantation Field Ditches, by H. A. Wads-

worth (Hawaii. Planters' Rec. 37: 92–95. 1933); Some Physical Constants for Certain Hawaiian Sugar Cane Soils, by H. A. Wadsworth (Hawaii. Planters' Rec. 37: 106–113. 1933); A Historical Summary of Irrigation in Hawaii, by H. A. Wadsworth (Hawaii. Planters' Rec. 37: 124–162. 1933); Irrigation is Highly Developed, by H. A. Wadsworth (Honolulu Star-Bull. Hawaii Farm Ann., Dec. 16, 1933, p. 11); Soil Moisture and the Sugar Cane Plant, by H. A. Wadsworth (Hawaii. Planters' Rec. 38: 111–119. 1934); On setting the Crest Elevation for the Parshall Flume, by H. A. Wadsworth (Hawaii. Planters' Rec. 38: 157–159. 1934); The Dairy Industry of Hawaii, by L. A. Henke (Honolulu Star-Bull. Hawaii Farm Ann., Dec. 16, 1933, p. 16); Pineapple Plants as Forage for Cattle, by L. A. Henke (Pineapple Quart. 4: 1–6. 1934); Territory Can Grow Dairy Feed, by C. P. Wilsie (Honolulu Star-Bull. Hawaii Farm Ann., Dec. 16, 1933, p. 18); Commercial Poultry Production and Marketing in Hawaii, by H. L. Chung, A. S. T. Lund, and C. M. Bice (Univ. Hawaii Ext. Bull. 20. 1934); Poultry Industry Grows Rapidly, by C. M. Bice (Honolulu Star-Bull. Hawaii Farm Ann., Dec. 16, 1933, p. 23); Fertilizing is Good Investment, by J. C. Ripperton (Honolulu Star-Bull. Hawaii Farm Ann., Dec. 16, 1933, p. 10); A Comparison of Legume Intercycle Crops for Pineapples, by O. C. Magistad, N. King, and O. N. Allen (Jour. Amer. Soc. Agron. 26: 372–380. 1934); More Interest in Fruit Growing, by W. T. Pope (Honolulu Star-Bull. Hawaii Farm Ann., Dec. 16, 1933, p. 36); and Research Aids Minor Industries, by J. M. Westgate (Honolulu Star-Bull. Hawaii Farm Ann., Dec. 16, 1933, p. 9).

SOILS

Continued work on factors affecting the ratio of the moisture equivalents of soils to their permanent wilting percentages indicated that the numerical value of this conventional ratio is, except in rare cases, independent of the textural classification. No significant differences in the ratios were found when Hawaiian soils were diluted with as much as 90 percent coarse silica sand. In still further dilution it is probable that the ratios would increase. The large probable errors involved with each of the determinations when large amounts of sand were used, however, made the results unreliable.

The necessity of working with small amounts of material in studying the availability ratios of the individual constituents of the soil has resulted in an indirect measure of these values. When this procedure is used samples of the soil separate in question are wetted to the moisture equivalent and brought into equilibrium with streams of air of known relative humidities. The probable wilting percentage may be deduced from the moisture contents and the surface forces involved at each of the equilibria.

No great precision may be expected from this procedure, but it promises to be a useful tool in locating the range of available soil moisture with separates that are available only in small quantities.

FIELD CROPS AND FORAGE PLANTS

RICE

The cooperative fertilizer experiments begun last year with the agricultural extension service of the University of Hawaii and with

the rice growers on the Island of Kauai were continued. The first crop was harvested and the crop replanted and fertilized for the second season's growth. The results show that for this soil nitrogen is the chief fertilizer element which is lacking. On the phosphorus-potassium plats without nitrogen the yield averaged 31 bags (100 pounds each) of paddy per acre; with nitrogen, the yield increased to 56 bags. There were slight but not significant responses to phosphorus and potassium. The nitrogen was in the form of ammonium sulphate only. In this experiment the phosphorus and potassium were applied in small furrows and the seed drilled in soon after. The nitrogen was applied about 45 days later, about the customary time for the application of complete fertilizer in ordinary practice.

Pot tests with rice, by the Mitscherlich method, using soil taken from the experimental field, were carried out in the station greenhouses. These pot experiments showed good correlation with the field results. A simple device for maintaining a constant depth of water has been found effective. A 1-quart bottle is held inverted at the edge of the pot by means of a wood-and-wire frame. The neck of the bottle extends down inside of the pot to the level at which the water is to be maintained. The bottle is filled with water once a day and the water keeps at a constant level after the manner of automatic poultry drinking fountains. Terra-cotta pots 10 inches in diameter and holding about 6 kilograms of soil are used. These are pretreated with paraffin dissolved in gasoline to render them impervious.

As an aid to the rice growers, soil samples sent in from the Moloaa, Hanapepe, and Wailua districts of Kauai were tested by the pot method for their response to the three fertilizer constituents. The results have been sufficiently conclusive to warrant the recommendation that the fertilizer practice be changed so as to maintain the nitrogen at its present level and reduce the phosphorus and potassium to one-half the present amounts. In the meantime any possible deleterious effect of this change is being studied by means of the continuous field experiments. The use of nitrogen only is not recommended, however, as indications have been obtained that the quality of the rice is adversely affected by nitrogen alone. Fertilizers are expensive, and reduction in the cash outlay in the production of rice in Hawaii is imperative if the industry is to persist.

PIGEONPEAS

Isolating and purifying strains by self-fertilization was continued. Selfing was accomplished by covering unopened buds with closely woven muslin bags and allowing the seed to ripen in the bags.

Experiments to determine the extent of natural crossing between varieties were completed. Approximately 15 percent of natural hybrids were obtained in progenies of open-pollinated plants that had been growing in rows adjacent to other varieties. A complete report of this work was submitted for publication in the Journal of Agricultural Research.

SOYBEANS

The testing of varieties was continued, emphasis being placed on those that were considered promising for green vegetable use. Yellow Biloxi Hybrid, a selection obtained through the courtesy of P. H. Kime, North Carolina Experiment Station, appeared to be quite

desirable from the standpoint of yield and quality. Two varieties, F. P. I. No. 80483 and 81780, secured through the courtesy of W. J. Morse, U. S. Department of Agriculture, gave excellent results in cooking tests for use as green vegetable beans. Twenty-one new varieties were obtained during the year from Dr. Morse for adaptation studies.

GRASSES AND LEGUMINOUS FORAGE CROPS

ADAPTATION STUDIES

Considerable attention was given to the introduction and establishment of more desirable species for pasture and green fodder use (fig. 3). Through the maintenance of a series of grass gardens at

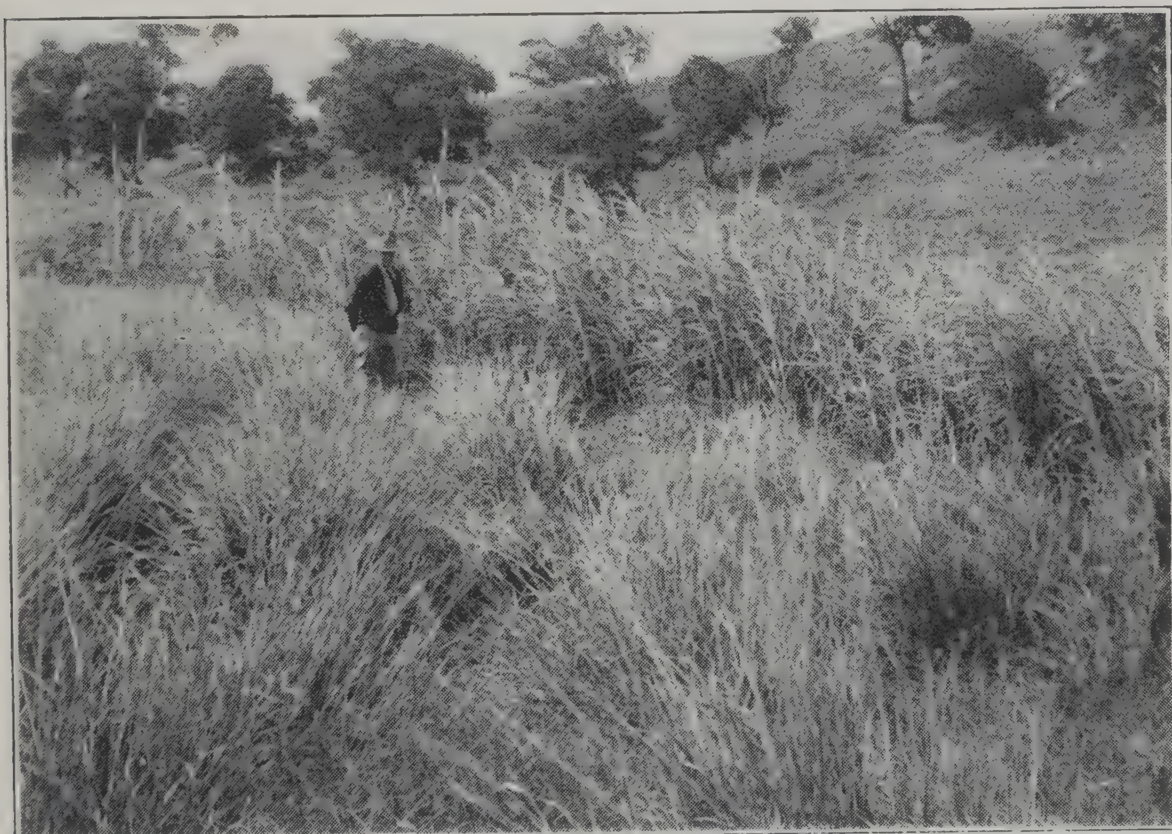

FIGURE 3.—Guinea grass (*Panicum maximum*) in foreground; elephant grass (*Pennisetum purpureum*) in background. These coarse grasses are making a vigorous growth at 2,200 feet altitude on the windward side of Hawaii. In this section, where the sod is nearly pure Hilo grass (*Paspalum conjugatum*), these coarse grasses offer excellent possibilities in the development of fattening paddocks.

the central station in Honolulu, the Haleakala substation on Maui, and cooperating ranches on the various islands, a large number of grass and legume species were studied for adaptation to different ecological conditions. One of the striking observations made was that kikuyu grass (*Pennisetum clandestinum*) was successfully established over a wide range of climatic conditions at elevations of from sea level to 6,400 feet. Rhodes grass (*Chloris gayana*) also succeeded under a wide range of conditions, but its adaptation is undoubtedly centered below 4,000 feet elevation. Wetland trefoil (*Lotus uliginosus*) was one of the most promising legumes, growing well at from 2,000 to 4,000 feet elevation and being particularly adapted to mixed plantings, making an excellent growth with kikuyu grass.

At the higher elevations, beginning at about 3,000 feet and extending up to 6,000 feet and higher, many of the Temperate Zone

species and particularly *Lolium perenne*, *L. multiflorum*, *Festuca elatior*, *Bromus unioloides*, and *Dactylis glomerata* were very promising. At these levels the most successful legumes were perennial Australian red clover (*Trifolium pratense* var.), New Zealand white clover (*T. repens*), several vetches (*Vicia* spp.), and alfalfa (*Medicago sativa*).

Due to the commonly experienced periods of severe drought such as was prevalent in many of the ranch areas in the summer of 1933, the establishment of drought-resistant species is of particular importance. Species that showed remarkable drought-resistant qualities were Rhodes grass, giant Bermuda (*Cynodon dactylon* var.), molasses grass (*Melinis minutiflora*), pigeonpea (*Cajanus indicus*), birdsfoot trefoil, and alfalfa.

New introductions, which appeared to be worthy of more extensive trials, were *Andropogon rufus*, *Indigofera hirsuta*, and *Stylosanthes guyanensis* var. *subviscosus*. These were obtained through the courtesy of the Experiment Station for Agrostology, Deodoro, Brazil. The agricultural extension service of the University of Hawaii cooperated in these adaptation studies.

LIFE-HISTORY AND STRAIN STUDIES

Preliminary studies were made in the flowering and seeding habits of Napier and Merker grasses, two varieties of *Pennisetum purpureum*. The blooming period of a single flowering head was found to extend over a number of days, the anthers emerging about 4 days later than the stigmas. Cross-pollination seems to be the rule in this species, although some seed was produced under vegetable-parchment bags from inflorescences covered before stigma emergence. Seedlings from both open-pollinated and selfed plants of both varieties were grown. A large number of growth types and distinct morphological variations have been noted in these seedling progenies, and the selection of superior forage strains seems quite feasible. As this species is propagated commercially by asexual means, strains possessing hybrid vigor or other desirable factor combinations could be maintained readily without the necessity of obtaining them in a homozygous condition.

Similar studies were also started with Sudan grass (*Sorghum vulgare sudanense*), guinea grass (*Panicum maximum*), and panicum (Para) grass, (*P. purpurascens*).

EFFECT OF LOCATION, SPECIES, AND SEASON ON QUALITY OF PASTURE GRASSES

Bimonthly harvests during a period of 14 months of grasses from the four grass gardens located on the Parker ranch were completed. Two hundred samples were each analyzed for moisture, total and silica-free ash, protein, calcium, and phosphorus. Unusually dry weather made it impossible to get a complete series of samples from each location. The results, however, showed a number of differences in quality of the grasses due to location, species, and season, which were statistically significant. For this comparison, five grasses were used: *Phalaris tuberosa*, paspalum (*P. dilatatum*), Rhodes grass (*Chloris gayana*), tall fescue (*Festuca elatior*), and kikuyu (*Pennisetum clandestinum*). With the exception of the last named, the grasses were clipped close to the crown of the stool every 2 months

so that the samples represented a 2-month growth. In the case of kikuyu, a creeping grass, only the fresh growing tips were taken for analysis. Most striking was the effect of location on the phosphorus content of the grasses. The poorest location (the leeward, dry grass garden) was scarcely 30 percent of the best in this constituent. The percentage of calcium was also affected, the windward, wet location being the poorest. Protein, on the other hand, was remarkably constant for the four locations.

Using the so-called "pairing method" of statistical analysis, it was possible to show significant differences among the five species. Season, too, seemed to have an effect, the poorest quality being found during the season of least growth, i. e., the cold winter months. Of the three factors—location, species, and season—the first named had much the greatest effect on the mineral content. The differences between the grass species on this basis of comparison were generally not great.

QUALITY OF FORAGE AS AFFECTED BY FERTILIZERS AND STIRRING THE SOIL

Former experiments with top-dressing of pastures with nonnitrogenous fertilizers showed a general lack of response except in cases of extreme deficiency. This, together with the oft-noted stimulation resulting from plowing and disking of the pasture sod, suggested the possibility that the fertilizer was not carried down to the grass roots or that the sod required stirring in order to stimulate the absorption of the fertilizer. To test this hypothesis, an experiment was begun on Grove farm, Kauai, comparing the effect of fertilization alone, fertilization plus plowing, and plowing alone. The fertilizer consisted of 1,000 pounds of phosphate fertilizer per acre—600 pounds as raw rock and 400 pounds as superphosphate. The area being used is one that is reputed to produce forage deficient in phosphates.

FRUITS, VEGETABLES, AND NUTS

AKALA OR NATIVE RASPBERRY AND OTHER RUBUS SPECIES

During the past year this work has included a study of both native and exotic species. Practically all but the most recent introductions are growing in a wild state as a part of the natural vegetation. The kinds of *Rubus* most commonly found consist of the akala (native raspberry) of two species, *Rubus hawaiiensis* and *R. macraei*, the thimbleberry (*R. rosaefolius*), and several varieties of American blackberries, dewberries, and raspberries.

The akala grows in moist land at altitudes ranging from 2,500 to 7,000 feet. In places, the two species form the main under-shrubbery of the forest and occasionally occur in mixed stands. The plants are eagerly devoured by livestock, and in range sections only plants in places inaccessible to the livestock may be found in fruit. Where the animals are kept out, as in new forest reserves, the plants spring up quickly and in great numbers as root suckers and seedlings. Seeds no doubt are disseminated to a considerable extent by birds. The stems and branches of the current year's growth of both species are more or less covered with tender green spines, but these are shed with the bark during the growth of the

second year as the stems become woody. The plants are not regarded as undesirable.

Rubus hawaiiensis is of upright form and often reaches a height of 8 to 10 feet. The individual plant usually consists of a clump containing several upright woody stems which continue to grow for a number of years, and in favorable conditions each may attain a diameter of 1.5 or 2 inches. Ordinarily, the fruit begins to ripen by April 1 and may be found as late as July. At maturity, the fruit averages 1.25 inches in diameter and occurs in two varieties, the dark purple and the yellow. The color of the fruit, however, is the only character distinguishing them. The flavor is often fair. *R. macraei* is a deciduous form with long arched canes with spines and scaly bark very similar to *R. hawaiiensis* but is later in coming into fruit, its season of bearing being from mid-July to November. The fruit averages 1 to 2 inches in diameter and is of a blue-black color and possesses various degrees of bitterness. These two species have been found on all of the larger islands except Oahu, but in this experiment was transplanted to 3,500 feet altitude on Oahu from the Island of Hawaii. Their cultivation has been undertaken at the Kona substation, 1,500 feet altitude, but the plants have not been vigorous and have failed to fruit.

The thimbleberry (*Rubus rosaefolius*), indigenous to southeastern Asia and the Philippines, is of early introduction into Hawaii. It now grows as a part of the natural vegetation in many places from near sea level to an altitude of 6,500 feet. The attractive but insipid light-red fruit is edible but the species is generally considered a pest. The canes and branches are thorny and the plants utilize considerable land in pastures and elsewhere which is desired for other plants.

Blackberries of several varieties, introduced many years ago, have formed thickets in several parts of the Territory. Although the fruit is used considerably, there is fear that they may soon become a very undesirable pest. The exact species has not as yet been satisfactorily determined. There are evidently two varieties, the most common being an evergreen type occurring on the Islands of Hawaii, Maui, and Oahu, and a deciduous form near the village of Holualoa on the Island of Hawaii. A few plants of the mammoth thornless blackberry were recently introduced, and, with two varieties of the dewberry, are in cultivation at the central station in Honolulu. The latter consists of a few plants each of the Youngberry and the Gardena dewberry. These, and the mammoth thornless blackberry, are being cultivated at several different elevations to determine their action under Hawaiian conditions. Former introductions of raspberries have failed to endure. Recent introductions by the station have been made from the mainland of the United States. These American varieties also have mostly died. One species from the Philippines, *R. niveus*, and a wild form from Java, have made considerable vigorous plant growth but as yet have shown but little inclination to fruit.

Not finding sufficient blossoms in the trial plats for hybridizing in April 1934, it was decided to collect pollen from blackberry plants in the Kilauea section of Hawaii and from another variety growing in the edge of the woods at an altitude of about 2,000 feet near

Holualoa, North Kona, and from the wild thimbleberry (*R. rosaefolius*) in South Kona, Island of Hawaii. The flowers were collected on April 19 and taken to a forest reserve on Mount Hualalai at 6,000 feet, where there is a good stand of *R. hawaiiensis* and *R. macraei*. Forty flowers of the native species were hand-pollinated and covered with cellophane bags, which, at that high, cool location in the partial shade of the woods, proved very satisfactory. Thirty-two days after pollination, a considerable number of the hybridized flowers had developed into fruit.

POTATOES

Variety tests of potatoes conducted on Oahu and Maui continued to show the superiority of the Bliss Triumph among the early red-skinned types and British Queen among the white varieties. The new variety, Katahdin, grown from Oregon seed stocks, gave excellent results in preliminary trials.

Nine varieties of potatoes were imported from New Zealand through the courtesy of the New Zealand Government Pure Seed Station. These were compared with Bliss Triumph and Earliest-of-All varieties grown in Hawaii. Only one of the New Zealand varieties gave a yield that compared favorably with the American varieties, and this (Up-to-Date) produced at the rate of 129 hundredweight per acre as compared to Waimea-grown Triumphs that produced 160 hundredweight per acre. These New Zealand varieties did not seem to be well adapted to Hawaiian conditions. Although all varieties were certified in New Zealand, the percentage of virus diseases was quite high in the field plats, showing, perhaps, that under Hawaiian climatic conditions the development of those diseases is more pronounced than under the cooler conditions of New Zealand.

Experiments on the production of disease-free seed stocks of the Triumph variety in Hawaii indicated that excellent seed potatoes could be grown at high elevations (5,000 feet) if the fields were carefully rogued for all diseased and weak plants. Yields obtained from such locally produced seed were higher (in variety tests) than those obtained from any other seed lot, including mainland certified seed of the same variety.

Three potato-fertilizer experiments were conducted on the Island of Oahu in cooperation with the local pineapple industry (fig. 4). These experiments consisted of comparisons of 9 treatments with 10 replications each. The treatments included 4 different amounts of phosphorus, in form of superphosphate, 2 of nitrogen, in form of ammonium sulphate, and only 1 of potassium, in form of potassium sulphate. The results showed in all cases a marked response to increments of phosphorus even in amounts as high as 1,000 pounds of superphosphate per acre. The plats receiving ample nitrogen and potassium but no phosphorus gave a yield of about 40 bags (100 pounds each) of potatoes per acre, while the yield when phosphorus was applied averaged 110 bags per acre. The response to nitrogen was variable, depending on the soil, the average being an increase of about 25 bags per acre over the phosphorus-potassium plats. Response to potassium was nil in all cases. For this type of soil, which is the ordinary red upland soil commonly used for pineapples,

a fertilizer mixture containing 12 percent nitrogen, 30 percent phosphoric acid (P_2O_5), and 6 percent potash (K_2O), at the rate of about 800 pounds per acre, is recommended. On the basis of the relatively low cost of fertilizer as compared with the other costs incident to growing potatoes in Hawaii, this high rate of application appears justified on the basis that it insures sufficient plant food for a bumper crop, given favorable weather conditions.

SWEETPOTATOES

Seventy varieties were tested for yield and 20 of these were used in cooking tests. Many were found to have rather poor quality for baking, being dry and tasteless. A few, Laupahoehoe, Madeira,

FIGURE 4.—Potato-fertilizer experiment on lands of a local pineapple company. Note the small growth of the nitrogen-potassium (no phosphate) plat in the center foreground and right center in the background. Spraying with bordeaux mixture is being done with a type of machine used by the local industry for spraying the pineapples with iron sulphate.

Japanese Brown Sweet, Pumpkin Yam, and several new selections from the Union of Soviet Socialist Republics had excellent cooking qualities. A collection of Hawaiian varieties has been introduced at the station through the courtesy of J. S. B. Pratt, of Eleele, Kauai.

SWEET CORN

Due to the susceptibility of sweet-corn varieties to the corn-stripe disease, efforts are being made to develop resistant sweet-corn hybrids. Guam corn shows little injury from this disease and is being used in the breeding work. Crosses have been made between Guam and Surcropper Sugar, Narrow Grain Evergreen, Country Gentleman, and Golden Cross Bantam. So far there has been some evidence of disease resistance in the Guam sweet-corn hybrids, and the work is to be continued. In these crosses many types intermediate between the true starchy and sugary types have been noted.

CABBAGE

Two field experiments with Copenhagen Market cabbage were made in the volcano district, Island of Hawaii. One was on virgin soil, to determine the requirements for nitrogen, phosphorus, and potassium. The first crop showed a marked deficiency of both nitrogen and phosphorus, even though it was recently cleared forest land. An earlier experiment on a nearby cultivated area had shown a good supply of phosphorus in the soil. The discrepancy was, in all probability, due to the residual effect of previous fertilizations and points to the desirability, wherever possible, of conducting all field experiments for a period of two crops in the same rows. Especially is this necessary in the gardening districts where very heavy applications of fertilizer are made. It has been found that the second crop will show very marked deficiencies, which were completely masked in the first crop. The other experiment in this district is designed to determine the economic rate of application of a complete fertilizer for cabbage.

The soil of the volcano district is made up of volcanic ash from which certain of the fertilizer elements leach readily. Farmers, for that reason, find it necessary to apply fertilizer as many as three or four times for a single crop of cabbage. An experiment has been planned to study the feasibility of using organic forms of fertilizer instead of the cheaper mineral forms.

At Waimea, Island of Hawaii, a fertilizer experiment with cabbage was carried through the second crop. The first crop showed little deficiency of nitrogen, phosphorus, or potassium. The second crop showed a distinct need of phosphorus with moderate deficiencies of both nitrogen and potash. The third crop in the same lines is now being grown. In connection with each of these field experiments, pot tests were made with Sudan grass, as well as cabbage and kale. A very acceptable correlation appears possible with both Sudan grass and kale. The field experiments were made in cooperation with the agricultural extension service of the University of Hawaii.

LIMA BEANS

Several selections of Hopi lima beans, introduced through the courtesy of W. W. Mackie, University of California, gave excellent yields as compared with Fordhook bush and Henderson bush varieties. The Hopi lima strains showed a definite perennial tendency and bore two good crops of seed. Two of these strains showed resistance to the root-knot nematode, while the others, as well as the standard varieties, were very susceptible.

LETTUCE

The breeding of lettuce for adaptation to low elevation conditions was continued. Hybrids between Mignonette and Selection 1801 were promising, showing the fine heading characteristics of the Mignonette parent and the larger size of the 1801. The season was not favorable for the production of solid heads of good size, but an excellent crop of seed was harvested for future plantings.

MISCELLANEOUS CROPS

Variety tests were conducted with taro (*Colocasia esculenta*), cassava (*Manihot utilissima*), peanuts (*Arachis hypogaea*), tomatoes,

and garden beans. Several species of *Cracca* were grown to study the growth and adaptations to local conditions, and are being used for the extraction of rotenone, tephrosin, and other compounds for insecticidal use.

MACADAMIA NUT

PROPAGATION AND CULTURE

In cooperation with interested growers, several selections of Macadamia trees which have good horticultural records were made. These trees are vigorous and prolific, and the nuts are first class as to size, roasting qualities, and flavor. They are to be maintained as a source of graft wood for the development of true varieties by vegetative propagation.

FIGURE 5.—A recently transplanted grafted Macadamia-nut tree 30 inches high at Kona substation.

The grafting work previously started in an attempt to standardize varieties of the Macadamia nut has proved successful. In brief, the methods worked out are as follows: Macadamia seedlings are grown in the field in rows at right angles 2 feet apart each way. When the seedlings are 18 to 20 months old, they are grafted at about 2 feet from the ground, the union being of the side-tongue graft, details of which are given in a recent circular of the station (*8, p.* 8). The method gave about an 80-percent success, and by January 1933, and during each succeeding month, a few trees were dug up and transferred to a permanent place in other fields. The transplanting of the young Macadamia tree is often considered to be difficult. Figure 5 shows one of the trees several weeks after it had been reset in the station orchard.

Seedling trees grafted at 2 feet from the ground may have their crown branches formed anywhere from 3 to 4 feet above ground, which is a very satisfactory height for them in localities subject to considerable wind. Grafted trees tend to be slightly dwarfed, which is a good form for orchard trees, and such trees also tend to come into regular bearing at 6 to 7 years of age. Seedling trees are somewhat erratic and may not bear until 10 or 15 years of age.

At the present time there are approximately 20,000 Macadamia-nut trees distributed mostly among nine plantations in the Territory of Hawaii, and practically all of these are seedlings. The present crop

of Macadamia nuts is a miscellaneous collection varying in many ways and requiring much sorting and selecting until only a comparatively small quantity of high-grade nuts remains for marketing in competition with other kinds of nuts, most of which come from well-organized industries where the growers use only grafted varieties.

HARVESTING AND MARKETING

The ideal sequence from the harvesting of the Macadamia nut to the final cooking and packaging is to husk as soon as the nuts are gathered, then store for 3 or 4 weeks at a temperature not greatly in excess of 75° to 80° F. with good air circulation. Under conditions of ordinary humidity (70 percent saturation), the kernels dry in 3 or 4 weeks to 3–4 percent of moisture, without molding or development of off-flavors. Cracking, cooking, and packing can proceed at once. Excessive temperatures, high humidity, poor air circulation, or too long a period of storage after air-curing are to be avoided.

The main bulk of the crop drops during a 4- or 5-month period, beginning with July. This necessitates storage of the nuts after they are harvested and cured. An experiment was begun to study (1) storage as uncracked nuts versus extracted kernels; (2) temperature of storage—20°, 32°, 40° F., ordinary room temperature, and hot-room temperature; (3) moisture content—air-dry versus dehydrated nuts; (4) time of storage—3 months, 6 months, and 1 year; (5) storage in sealed versus open containers; and (6) storage as roasted nuts versus storage as cured nuts with subsequent roasting. The samples stored for 3 months were opened, roasted, and compared as to texture and flavor. The most important observation made was that the nut absorbs odors from the cold-storage room readily, the extracted kernels more so than the nuts in the shell, but even the latter could not safely be stored with miscellaneous vegetables or other food products. This same tendency to absorb odors has been observed in the use of various fumigants to prevent weevil infestation. The low temperatures had no apparent effect on the nuts after 3 months in cold storage.

As a factory procedure, dehydration of the extracted cured kernels at about 180° F. for several hours until the moisture content is reduced to about 2 percent, with subsequent storage in closed tins at 40° F., is apparently the most satisfactory method. This effectively kills the weevils, prevents molding or rancidity, and permits storage for protracted periods at a nominal cost. Since the Macadamia nut will be sold almost entirely as a roasted product, the storing of the extracted kernels appears to be the most feasible procedure.

One hundred and seventy-eight samples of Macadamia nuts representing all the principal localities in Hawaii where such nuts are being grown, and including both smooth- and rough-shell varieties, were graded as to quality. Monthly samples were taken from each tree throughout the harvesting season when practicable. Otherwise 1 or 2 samples per tree were tested. Through the cooperation of a local Macadamia-nut company, the entire series was run through the regular factory procedure. This consisted in (1) putting the nuts through a centrifugal "gun" which jars the kernel free inside the shell, (2) sizing the nuts into large, medium, small, and culls

(nuts too small to be accepted at the factory), and (3) extracting the kernel by means of a large-scale power cracking machine. Differences among the various samples in any of the three steps can thus be translated into terms of commercial significance.

Results of the year's tests tend to bear out previous observations that, as compared with the rough-shell variety, the smooth-shell nuts are of greater uniformity with less tendency to drop as immature nuts. It cannot be said with certainty that this is due entirely to variety since the smooth-shell and rough-shell samples come from different localities. The early drop of nuts from any given tree is usually high in immature nuts. The main crop, which falls during a 2- or 3-month period, is of the best quality. The late drops are of much better quality than the early drops.

It is especially encouraging to note the excellent quality of nuts from new seedlings growing among coffee in the Kona district. The interplanting of Macadamia and coffee would seem to have some very obvious advantages. Coffee does well under partial shade, so that interplanting with Macadamia at intervals of, say, 50 feet would not appreciably detract from the coffee yields for a long time, and the Macadamia could be brought to bearing age at a nominal cost.

Fertilizer experiments both in the field at Keauhou, Kona, and in pots at the Pensacola Street station, Honolulu, have been continued. It is too early to observe any effects of the different treatments.

COFFEE

VARIETAL STUDIES

The coffee trees used in the present coffee experiments have been in part in cultivation on the Islands of Oahu and Hawaii. The old grove of about 125 trees, located at the Tantalus substation, Island of Oahu, altitude 1,000 feet, which was planted some years ago for varietal study, has also been a source of propagating material. This grove consists of Hawaiian, Liberian, and a few trees each of *Coffea excelsa* and *C. robusta.* The early planting of the present experiment, made in 1931, consisted of 2-year-old trees of Hawaiian and Robusta varieties which are utilized for study of both cultural methods and habits of growth (fig. 6). In 1934 these trees produced a fair crop. The propagating work has been done mostly at the central station in Honolulu.

The work of accumulating seedlings and grafted stock has been in progress during the early part of 1934 for more extensive cultural trials in a new field of 1.66 acres, recently acquired, adjoining the Kona substation. The planting was begun with the early showers of the wet season, which began early in February. The kinds of coffee selected have been based upon the merits of each, as shown either in Hawaii or some other coffee-growing country. These merits or characteristics are vigor, productiveness, quality of grain, and root resistance to some sort of adverse soil conditions, particularly when employed as rootstocks following vegetative methods of propagation.

The names of the coffee varieties, origin, unusual characteristics, and arrangement of planting in the new field at the Kona substation are as follows:

Hawaiian (*Coffea arabica*), Arabian group; nativity, tropical Africa, but reaching Hawaii from Brazil. This variety proved adaptable to Hawaiian conditions; quality very good; planted in experimental field, one row, 22 selected seedling trees; one-half row, 11 grafted trees, scions united with Robusta rootstocks; one-half row, 11 trees grafted on Liberian rootstocks.

FIGURE 6.—Hawaiian coffee (*Coffea arabica*). Four-year-old tree in fruit, 7 feet high, at the Kona substation, Island of Hawaii.

Guatemalan (*C. arabica*), Arabian group; nativity, tropical Africa, but introduced from Guatemala; adaptable to Hawaii; quality very good, probably due to long period of seed selection in a country very favorable to its growth; one row, 23 selected seedlings; one-half row, 12 seedlings for pruning experiments; one-half row, 11 trees selected scions on San Ramon rootstocks; one-

half row, 10 grafted trees on Robusta rootstocks; one-half row, 13 trees on Liberian rootstocks.

Maragogipe (*C. arabica*), Arabian group; originated in Brazil; introduced into Hawaii from Java. It differs from other Arabian coffees in having larger cherries and beans than other varieties of the Arabian group; it also has a late-ripening season. In the field there is one row of selected seedlings for varietal test; one-half row for pruning test; one-half row for scion wood; one-half row, 11 trees grafted on Robusta stocks; one-half row, 12 trees grafted on San Ramon stocks.

Robusta (*Coffea robusta*), Robustoid group; native of Congo, Africa; received in Hawaii from Java, Mozambique, and Panama. It was the main coffee grown in Java in 1920, where it is also extensively used as a rootstock said to be very resistant to adverse conditions. One row of seedling trees for seed production; one row, 22 trees for scion wood; one-half row, 11 trees on Liberian stocks; one-half row, 11 trees on San Ramon stocks.

Padang (*C. arabica*), Arabian group; Sumatra variety. The beans are next largest to Maragogipe. One row of seedling trees for trial production; one-half row, 11 trees on Robusta stocks; one-half row, 11 trees on Liberian stocks.

San Ramon (*C. arabica*), Arabian group; originated in Central America from where it was received in Hawaii; a dwarf variety, fairly true in this respect from seeds; very prolific and late in maturing. One row of seedling trees for production; one-half row, 11 trees on Maragogipe stocks; one-half row, 10 trees on Liberian stocks; one row of seedlings for pruning experiments.

Excelsa (*C. excelsa*), Liberian group; discovered in western Africa. This variety ripens the main part of the crop in spring—cherries do not fall on ripening. The plant is very resistant to adverse soil conditions. One-half row for production; one-fourth row, 6 trees grafted on Liberian stock; one-fourth row, 6 trees on Robusta rootstocks.

Columnaris (*C. arabica*), Arabian group; supposed to be of Javan origin. The trees become large and vigorous and produce heavy crops. It has been known to produce well at an altitude of 3,000 feet. One row of seedlings for trial production and one-half row for rootstocks on which to graft several other varieties have been planted.

Miscellaneous varieties. One row of different kinds of graft unions; also grafts made at different seasons of the year.

PROPAGATION STUDIES

The coffee-grafting work of the past year has included propagation of nursery stock. The seedlings have been germinated in a medium of equal parts of rich loam containing considerable humus and coral sand in ordinary germinating flats of about 3 inches in depth. The seedlings in these flats require from 3 to 4 months' growth to attain sufficient size for transplanting into individual 4-inch containers, which are sufficient for another period of 4 to 6 months' growth. They are then transplanted to 8-inch containers, where they remain without serious root confinement for another 6 months. Within 18 months of growth from germination, the seedling is usually about 1.5 feet high and has a stem diameter near the base of about five-eighths of an inch. The seedlings are grown in the slat house with such other tropical plants as require partial shade. The conditions of coolness and humidity, which are desirable for vigor and uniformity of growth, particularly during the time the stock and scion of the graft are uniting, are thus maintained.

A simple form of graftage which has been employed to some extent in some other countries has been used very successfully at the Hawaii Station with seedlings of either the Liberian or Robustoid group. These kinds of coffee are known to have vigorous roots which are generally resistant to unusually cool or wet soils, attacks of nematodes, and possibly to some other soil disorders. The young seedlings of a month or 6 weeks' growth are transplanted from the

propagating flat to individual 3.5-inch plant pots. After having become established in these containers, which requires about 2 months, the seedlings may be cleft-grafted without the removal of the foliage. In making the union, the stem is cut off a little above the first or second pair of leaves and then split down through the middle for about an inch. The young, comparatively tender scion of about the same diameter and of the desired variety is prepared by cutting the basal end into a narrow wedge as long as the cleft and into which it is inserted and the union bound tightly with a flat strip of moistened raffia. This method of grafting has been successfully employed this year with coffee seedlings up to 18 months old in 8-inch plant pots.

Where very small seedling plants are grafted the small size of stem naturally requires small scions which are only obtainable as seedling scions, but where such scions are from desirable seedling varieties it proves satisfactory. Rootstock seedlings, having a diameter of 0.5 inch or more, however, will unite with larger scions of trees of known quality, thereby producing true varieties.

PRUNING EXPERIMENTS

The two cooperative experiments, begun in 1932, comparing different pruning systems, were continued. These systems are: (1) Secondary vertical, in which much of the plant is permanent and the bearing surface is high up in the top; (2) multiple vertical, in which only 2 to 4 feet of the stump is permanent and new vertical branches are brought out periodically; (3) topping system; (4) modified topping system, in which the base of the plant is like that of the topped system and the top is similar to that of the multiple vertical; (5) tall vertical system in which the verticals are retained for a longer period than in the multiple vertical; (6) leaning vertical system, in which the verticals are maintained in a horizontal position. Plants pruned by these different systems are now showing marked differences in appearance and the results are becoming increasingly valuable as a means of comparing the different systems under identical conditions of soil and climate.

The systematic pruning experiment, in which a study is being made of the feasibility of removing and forcing out the same amount of wood each year, was continued. From the standpoint of field experimentation, such pruning offers possibilities of reducing the tremendous fluctuation in yield of a single tree from year to year which occurs with the ordinary pruning methods.

Girdling, as a means of insuring the development of a low-setting vertical on the old vertical to be removed the following year, was successful in about 90 percent of the girdles. The shoots, which set on, did not always develop rapidly enough to be of appreciable size at the end of the season. There is also some evidence that girdling affected the size of the cherry and the amount of die-back on the girdled vertical. This method requires further experimentation to determine its value.

The coffee die-back experiment was continued. The purpose of this experiment is to limit the amount of bearing of the young tree during the period when excessive bearing often gives the plant a set-back of several years. Under the climatic conditions of the

1933 season, die-back was not apparent in any of the plants in the young orchard in which the experiment is located.

EXPERIMENTS IN HAMAKUA

Fertilization of the coffee-rejuvenation experimental plats was discontinued, but periodic inspections were made of the new growth and systematic pruning was carried on. The moderate pruning method, whereby the old trunk, thickened laterals, and a small amount of young branches are left on the plant, appears to be the best method of renewing growth on the run-down plants. While this is a tedious procedure, it results in a loss of but one crop and can be used on plants of low vitality, where the more drastic stumping would probably kill a considerable number. The so-called "parrot-stick" method, whereby all growth is removed to within about 12 inches of the old trunk, is likewise too drastic to be safely used on run-down plants. Response to fertilization in the Hamakua section is variable. In some fields good increases result; in others there appears to be ample plant food. Improper regulation of shade is often a limiting factor in production in this district.

EXPERIMENTS IN KONA

Results of the 1933–34 harvest of the Kainaliu fertilizer experiment gave 206 bags (100 pounds each) of coffee cherry per acre for the complete-fertilizer (nitrogen-phosphorus-potassium) plats, 202 bags for nitrogen-potassium plats, 51 bags for nitrogen-phosphorus plats, 61 bags for plats receiving nitrogen only, and 65 bags for the check plats. The complete fertilizer used in this experiment is 2,000 pounds per acre of a mixture containing 8 percent each of nitrogen, phosphoric acid (P_2O_5), and potash (K_2O). These results are very similar to those of the two previous seasons.

The nitrogen-phosphorus and nitrogen plats made a fairly good growth of new wood during the previous season, and it seemed possible that the 1933–34 crop from these treatments might approach those of the high-yielding nitrogen-phosphorus-potassium and nitrogen-potassium plats. It became evident as the season progressed that potassium plays an important part in the development of the fruit. In spite of a normal set of fruit, die-back became increasingly evident in the nitrogen-phosphorus and nitrogen plats. The amount of cherry which died back was collected and weighed separately from the normal cherry. In the nitrogen-phosphorus-potassium plats, die-back was at the rate of 0.2 bag per acre; in the nitrogen-potassium plats, 0.8 bag; in the nitrogen-phosphorus plats, 6 bags; in the nitrogen plats, 12 bags; and in the check plats, 4 bags per acre.

Pot experiments at the Pensacola Street station, Honolulu, using coffee seedlings grown in soil from the Kainaliu experiment, show very strikingly this same difference in the functions of phosphorus and potassium in the nutrition of the coffee plant. The trees are 20 months old and fruited for the first time this season. Previous to blooming, the nitrogen-phosphorus-potassium and nitrogen-phosphorus trees were nearly equal in size and vigor, with the nitrogen-potassium plants far smaller. With the appearance of fruit buds, the nitrogen-phosphorus plants began to drop many of their leaves, and scarcely any blossoms opened. The nitrogen-phosphorus-potas-

sium plants blossomed freely and set fruit normally. The nitrogen-potassium plant is small in size but otherwise normal and sturdy. This suggests the possible advantage of different fertilizer formulas for young trees and for full-grown trees in heavy bearing.

Many growers have noticed the tendency of plants fertilized with nitrogen only to die back. Moreover, the quality of the bean appears to be adversely affected. Although the results from the Kainaliu experiment are conclusive for this one location, it should be emphasized that further experimentation is necessary to establish their application to the district as a whole. With this in view, two similar experiments were established, one in North Kona, Holualoa section (1,400 feet altitude), and the other in the Kealakekua section (2,100 feet altitude). The former is in a 5-year-old field, and the latter in an old field of topped coffee. If results of these experiments substantiate the conclusions of the Kainaliu experiment, it will be possible to effect changes in the fertilizer formulas which will result in a much more efficient use of the fertilizer applied.

Analysis of seven samples of coffee cherry taken from widely different locations in Kona showed a fluctuation in the potash content of from 1.67 to 4.03 percent. The pulp from the nitrogen-phosphorus-potassium plats of the Kainaliu experiment contained 3.08 percent, while that from the check plats contained 1.67 percent. Variations in the nitrogen and phosphorus content were apparent but less pronounced. This suggests the possibility of analysis of the coffee pulp as a criterion of the nutritional needs of the coffee plant.

COMPOSTING OF COFFEE PULP

Analysis of the compost from the experimental compost pit at the Kona substation showed a loss of about 50 percent of the total dry matter before decomposition was complete. One ton of fresh coffee pulp, to which 60 pounds of limestone and 25 pounds of superphosphate had been added, produced about 1,000 pounds of final compost with a composition of 2.9 percent nitrogen, 2.7 percent phosphoric acid (P_2O_5), and 3.1 percent potash (K_2O). Observation of the compost pits built by the Kona farmers indicated that anaerobic decomposition proceeds too slowly to be feasible. Apparently, it will be necessary to turn the compost at least twice to effect decomposition in, say, a 7-month period so that the pit can be emptied and the compost applied on the fields during the ensuing summer. To test the effect on speeding up the rate of decomposition, the station compost pit was filled with fresh pulp mixed with thin layers of soil, plus limestone and superphosphate, the purpose of the soil being to furnish a source of organisms capable of more rapid decomposition than those normally present in the coffee pulp.

Farmers recognize the value of coffee pulp as a fertilizer. Fields receiving regular applications show stronger growth with less dieback than those receiving commercial fertilizer only.

ECONOMIC TROPICAL ARBORETUM AND ORCHARDS

The economic tropical arboretum now contains about 600 species. Some of these species, which have already indicated considerable possibilities in Hawaii as cultivated orchard crops, contain many varieties growing in group plantings. Among these groups are:

Annona, avocado, banana, breadfruit, cashew nut, citrus, coffee, date, fig, litchi, longan, Macadamia nut, mamey apple, mango, mulberry, papaya, passion fruit, and sabucaya.

The citrus orchard, which has been developed in connection with many years of experimental work, consists of 238 trees, including 40 different species and varieties. This orchard is a constant source of information in reference to varieties, cultural practices, and insect and plant-disease control, and has supplied propagating material for use in cooperative experiments throughout the Territory. Much of the experimental work in the citrus orchard is discussed in a recent bulletin of the station (*6*).

The avocado, mango, litchi, and date orchards have received attention by the station and have also been made available to the Bureau of Entomology of the United States Department of Agriculture for its fruit-fly investigations.

ANIMAL PRODUCTION

DAIRY

The dairy herd was reduced from 60 to 51 head (including cows, bulls, heifers, and calves) during the year and now consists of 40 Holstein-Friesians and 11 Guernseys. Three young bulls were purchased to replace older animals that were no longer giving satisfactory breeding service.

The general condition of the herd is good. It is free from tuberculosis, and animals positive to the agglutination test for abortion are kept in separate pastures.

The herd not only provides animals for experimental work but is also a laboratory for students in dairy husbandry.

Alfalfa hay was used to supplement the green roughages fed to dairy cows in two 15-week experiments, one with 8 and the other with 6 cows. This resulted in no significant increase in milk yield, but did materially increase the cost of milk production.

Green Sudan grass was compared with green panicum (Para) grass in two experiments each with 6 cows. One experiment lasted 9 and the other 12 weeks. In each case the cows consumed more of the Sudan grass and the milk yields were slightly higher.

The leaves and stumps of pineapple plants (shredded) were fed to three 600-pound Holstein heifers as their sole roughage for 147 days. Consumption ranged from 22 to 45 pounds daily per heifer, depending on the kind and quantity of supplementary concentrates given. No high value was indicated for pineapple plants in this trial, but it was demonstrated that cattle will eat considerable quantities of them and that plants in old or abandoned pineapple fields may be used as emergency feeds in periods of drought.

Cane molasses to the extent of 25 percent of the concentrate mixture was fed for a 7-year period to many cows in the herd (153 cow-years) and the records of 6 years on a nonmolasses ration (146 cow-years) were used as controls. In general, the results show that, when properly supplemented with high-protein feeds, cane molasses in the amounts indicated does not adversely affect production or reproduction or increase the number of abortions and it does result in a material saving in the cost of milk production under conditions prevailing in Hawaii.

No definite benefits were noted from feeding sprouted oats to cows with an irregular breeding behavior, and results to date indicate that under conditions prevailing in Hawaii (green feed available the year round) this method of correcting breeding troubles has little value. To date, 53 cows have been fed sprouted oats.

SWINE

At the close of the fiscal year 1934 the swine herd included 5 Berkshire and 6 Tamworth breeding animals and 17 smaller pigs. At the beginning of the year the herd numbered 44 animals. The reduction in the size of the herd was brought about as a necessary economy measure.

Further work on the feeding value of avocados or papayas (cull or excess fruits in regions distant from market) indicate a fairly high value for avocados and a much lower value for papayas.

Cooked taro scraps (refuse from poi factories) were found to have a fairly high value as a hog feed.

Feeding sprouted oats to sows with an irregular breeding behavior was continued. Not all the sows were benefited but their records were better than those of an equal number of controls, also with breeding troubles, to which sprouted oats was not fed.

POULTRY

The poultry husbandry division maintains a flock of approximately 2,000 chickens, turkeys, and guinea fowls, comprised of breeds commonly found on the commercial farms in Hawaii, for purposes of instruction, demonstration, and research.

ARTIFICIAL ILLUMINATION FOR LAYING STOCK

Pullets that are hatched in November, December, January, and February have a tendency to go into a partial or complete molt before a full year of laying. All-night illumination was tried on early-hatched pullets but proved to be unsatisfactory. For the past 2 years the lights have been turned on at 4 a. m., beginning on September 1 and terminating on March 1. Analysis of the data gathered over the past 2 years shows that the 4 a. m. lighting system has given satisfactory results. Early-hatched pullets did not go into a complete molt during the fall months; likewise the partial molt was reduced approximately 75 percent by the increased length of day. Body weight, after a year of laying, was very satisfactory; practically in all hens a decided gain was noted. Egg production has been greatly increased. The pens on artificial lighting averaged 50 percent more eggs during the months that they were under lights over that produced by the check pens receiving no artificial illumination. A greater number of culls appeared in the check pens, although the mortality was approximately the same for both groups.

A few poultrymen have cooperated with the station in this work, using their commercial flocks from which to obtain data under field conditions. Data from these field trials have not been analyzed to date; however, an increased production and less culls have been reported by all collaborators.

TREE KALE (CHOU MOELLIER) AS A SOURCE OF GREEN FEED FOR POULTRY

Comparison of tree kale with alfalfa as a source of green feed for poultry, which has been in progress for 2 years, indicates that tree

kale is comparable with alfalfa for egg production, fertility, hatchability, and body development.

BATTERIES FOR LAYING AND BREEDING STOCK

The first attempt to house laying hens in hen batteries was made during the year by the Hawaii Station. The hens were divided into three groups according to their breeding, development, and condition. One-half the birds in each group received a fermented yeast mash daily containing 1 percent of "animal-poultry yeast"; furthermore, the three groups were on an entirely different feeding method. Three types of commercial feeding methods were used, namely, the all-mash, mash and scratch, and pellets and scratch. Fermented yeast mash gave best results in all three feeding methods above mentioned. The birds were in better condition at the end of the experiment; they laid approximately 30 eggs more per hen when fed 1 percent of yeast in mash that was fermented for 18 hours. Mortality was approximately the same in all groups. The average yearly production per hen for the entire group was 200.6 eggs. One hen laid 300 eggs and another 297 during the period of the experiment which lasted 365 days.

PLANTATION BACK-YARD POULTRY HOUSES

Four types of houses, each with a floor area of 72 square feet and accommodating 25 hens, were tried with the object of finding a house that was cheap and yet efficient for the back-yard plantation poultry raiser. One year of work on this problem shows that egg production was maintained in a satisfactory manner in all four houses; that the birds in an all-lath house gave the lowest production, whereas the best production was obtained from birds in an 8 by 9 foot house with a solid back and a wire front.

Considerable cannibalism in the form of feather pulling was noted in all four houses. Previous trials at the Hawaii Station have shown that where birds were kept in close confinement, cannibalism was one of the most serious problems with which to contend. Blueprints of the four types of houses have been made and are available to those interested.

SOREHEAD (FOWL POX) CONTROL

In studies of sorehead extending over 7 years, the object has been to determine the method of transmission of the disease to chicks, poults, and squabs, and also to determine the effects of a "live virus" vaccine in developing immunity against the disease. The results of elimination of mosquitoes from the house and run indicate that the mosquito carries the virus to the chick. Chicks 4 to 12 weeks old and poults 3 to 16 weeks old have been successfully vaccinated with a live virus vaccine prepared by the station. In field trials, as a demonstration to show the value of fowl-pox vaccine, approximately 250,000 chicks have been vaccinated successfully. The procedure and the results of this experiment under laboratory and field conditions are described in detail in a circular of the station (*3*).

GIZZARD-WORM CONTROL

The object of this investigation is to determine the cause of the gizzard-worm infestation in Hawaii, particularly in regard to an intermediate host which may be responsible for this new disease. It

was started only within the last quarter of the fiscal year 1934. Considerable losses have been caused directly or indirectly by this worm. One farm reports a loss of approximately 3,000 hens in a period of 1 year. The worm is found on all of the islands; hardly a farm has escaped an attack of this parasite. Not only a high mortality but apparently a decided lowering of egg production has resulted.

There has been very little scientific research on this worm by mainland institutions, primarily because the worm has not infested the large poultry centers. All information received from mainland investigators state that the grasshopper is the intermediate host responsible for the gizzard worm. The station has made a study of infected gizzards, noting especially the physiological characteristic of both male and female worms. Several of the common insects found on most poultry farms in Hawaii have been studied, with no indication as to the intermediate host. Gizzard-worm eggs are being fed to baby chicks to determine whether or not infestation may occur without an intermediate host. Nothing conclusive as to an intermediate host or any other means by which the infestation has appeared in Hawaii has yet been found.

FOOD AND NUTRITION

IODINE CONTENT OF SOME HAWAIIAN MARINE FOOD PRODUCTS

In a continuation of an investigation to determine the iodine content of Hawaiian foods, 18 of the principal fish and 12 of the most widely used seaweeds have been analyzed. The general procedure followed was Remington's modification of McClendon's method, but it was found necessary to alter Remington's procedure in consideration of the particular characteristics of marine foods. To avoid loss of iodine, the bulk of the final ash was increased by adding to each sample before ashing 1 g of calcium carbonate and 2 cc of a saturated solution of sodium carbonate and moistening with hot water. This modified method replaced the Remington procedure, which involved soaking the sample with a 2-percent aqueous solution of sodium carbonate.

The experiments were carried out in duplicate and the results tabulated below show amounts of iodine expressed in parts per billion of the dry sample:

TABLE 1.—*Iodine content (in parts per billion of dry sample) of different marine foods*

Kind of food	Sample 1	Sample 2	Kind of food	Sample 1	Sample 2
Fish:			Fish—Continued		
Ahi	2, 100	2, 100	Ulua	2, 000	1, 800
Aholiholi	3, 300	3, 570	Weke ula	1, 910	1, 940
Aku	2, 600	2, 700	Seaweed:		
Amaama	1, 500	1, 800	Akiaki	411, 000	412, 000
Au	2, 270	2, 300	Alaula	127, 000	134, 000
Awa	2, 600	2, 750	Eleele	6, 408	6, 403
Hapuu	2, 390	2, 320	Huluhuluwaena	157, 000	143, 000
Kahala	2, 500	2, 540	Huna	1, 980	1, 970
Kala	3, 590	3, 500	Kala	487, 000	464, 000
Kawakawa	2, 700	2, 790	Kohu	5, 100	5, 500
Mahimahi	1, 941	1, 944	Lipeepee	13, 600	13, 700
Moelua	2, 600	2, 640	Lipoa	85, 400	85, 800
Moi	1, 950	2, 000	Manauea	149, 700	146, 300
Oio	1, 950	1, 900	Opihi	89, 100	89, 900
Opelu	2, 080	2, 020	Palahalaha	5, 200	5, 000
Uhu	5, 300	5, 000			

STEROL CONTENT AND VITAMIN VALUE OF AVOCADO OIL

The study of avocado oil for its vitamin D value was continued in a new series of feeding experiments with white rats. Animals were fed irradiated and nonirradiated samples of avocado sterol in alcoholic solution. The repetition of the entire vitamin D investigation was undertaken. In previous feeding experiments certain difficulties encountered led to inconsistencies in results. It is anticipated that the present set of animal experiments will lead to more definite conclusions concerning the vitamin D value of avocado oil and avocado sterol.

A CHEMICAL STUDY OF SOME HAWAIIAN PLANTS

POISONOUS PLANTS

Recognizing the fact that there are many poisonous plants of obnoxious character in the Hawaiian Islands, an investigation was started during the year to determine the chemical and physiological nature of the poisons in certain of the plants, and to isolate useful drugs and medicinals. Three plants, pamakani (*Eupatorium glandulosum*), akia, and air plant, were investigated for two common classes of plant poison, alkaloids and cyanogenetic glucosides. The three plants have been shown to be free from detectable quantities of alkaloids.

From pamakani a white crystalline solid melting at 68.5° C. was isolated which analysis showed to have the empirical formula $C_{25}H_{56}O$. Work is in progress to establish the chemical nature and the physiological action of this substance. Similar studies are in progress with akia and air plant and will be extended to other poisonous Hawaiian plants, about 80 of which have been listed.

PASSION FRUIT

The juice of the passion fruit is known to keep unusually long. A chemical and bacteriological study of the various components of the juice was made to determine the cause and, if possible, to isolate a preservative. No alkaloids or common preservatives were found and the conclusion was reached that the unusual keeping qualities of passion-fruit juice are due to high acidity.

VITAMIN B CONTENT OF FRESH DAIKON

Previous studies, which showed the nutritive value of vegetables to be increased by the Japanese method of pickling with salt and rice bran, were continued with the daikon or Japanese white radish (*Raphanus sativus longipinnatus*). The vitamin B of the rice bran was found to be absorbed by the daikon.

VITAMINS A AND D IN THE OPIHI (HAWAIIAN LIMPET)

Biological tests to compare the vitamin A and D content of the opihi with the international standards for these two vitamins showed this shellfish to be an excellent source of vitamin A and a very good source of vitamin D.

ANEMIA STUDIES

Anemia studies in cooperation with C. J. Hamre of the zoology department of the University of Hawaii were continued. The

enlarged spleens found at autopsy in anemic rats were correlated with definite stages of recovery from anemia, judging from the blood studies and histology of the spleens. Studies of young rats from birth to maturity showed similar correlations with the blood picture and the conditions of the spleens.

PROTEIN OF THE PIGEONPEA

Feeding experiments with white rats indicated that cystine had a growth-supplementing value when pigeonpea-seed meal was fed at a level to provide 11 percent of the protein in the diet, whereas, when fed at a level of 8 percent, cystine showed no supplementary value, possibly because at this level some other amino acid is the limiting factor.

VITAMIN CONTENT OF SOME HAWAIIAN FRUITS

Biological tests showed the papaya to be an excellent source of vitamins A and C and a good source of vitamin G, but only a fair source of B. Analyses showed the papaya to be a good source of calcium and sugar. The papaya is therefore a fruit of high nutritive value and should be more widely grown and used by all the peoples of Hawaii.

Although figs are a better source of calcium and iron than are papayas, figs are a fair or poor source of all the vitamins tested.

Pohas, though not an important or widely used fruit, were tested and found to be a good source of vitamins A, B, and C.

Previous experiments have shown that guava juice, prepared as for jelly making, has a high vitamin C content. The juice was prepared by slicing ripe guavas, placing in a saucepan and almost covering with water, bringing to a boil, and boiling gently for 10 to 15 minutes. The juice was stirred frequently to prevent scorching and then drained through a clean flour sack or other cloth. It was then ready for use. Experiments with 14 guinea pigs, 7 of which were fed daily 3 cc of guava juice and 7 a quantity of jelly equivalent to 2 cc of guava juice, showed little or no loss of vitamin C when the juice was made into jelly. This same jelly had no demonstrable quantity of vitamin A.

With the cooperation of a local pediatritian and the nurses at two of the well-baby clinics in Honolulu, it was possible to try out the use of guava juice in place of orange juice as an antiscorbutic for 10 normal babies. Several hundred quarts of guava juice were prepared and bottled, using an ordinary bottle capper. When stored in a dark place at room temperature, the juice kept perfectly for months. The guava juice, given out at the clinic and delivered to the homes, was the only antiscorbutic given for 6 months. The results showed that guava juice, prepared as for jelly making, may serve as a satisfactory antiscorbutic for infants. Many of the babies showed a greater rate of gain than the average for the clinic babies and there was no evidence that the guava juice disagreed with infants of 2 months and older.

JAPANESE FOODS AS SOURCES OF THE VITAMINS

Reports from Japan indicate that tofu (soybean curd) and miso (fermented soybeans and rice) are poor sources of vitamin B, but

preliminary tests in the station laboratory have shown them to be good sources of this vitamin. In addition to their value as sources of calcium, phosphorus, and iron, these two foods should be stressed for the Japanese diet because of their vitamin B content.

Preliminary tests showed miso to have no demonstrable quantity of vitamin A but to have considerable vitamin G.

Lotus root, used by both Japanese and Chinese, was found to have little or no vitamin A and to be only a fair source of vitamins B and G.

Chirimen-iriko, a very small dried fish used by the Japanese (*5, p. 15*), showed little or no vitamin G; rats fed 3 grams daily gained no better than the control. The dried fish, however, proved to be a good source of vitamin A, and a very good source of vitamin D.

HALEAKALA SUBSTATION

Work was continued at the Haleakala substation (elevation 2,162 feet) and on the four associated tracts located at elevation intervals of about 1,000 feet, with the highest at about 6,000 feet.

The extreme conditions of drought in the summer and fall of 1933 enabled the superior grasses and legume varieties under test to stand out in sharp contrast to the native range grasses in the associated pasture areas. The forage crops under test consisted of 32 varieties of grasses, 166 lots of pigeonpeas, 17 varieties of clover, as well as plantings of alfalfa, vetches, and *Meibomia rensoni*.

The root and tuber crops included edible canna, cassava, taro, arrowroot, as well as 25 varieties of potatoes, including the Bliss Triumph, upon which special work is being done to determine its value for new potato shipments to the mainland during January and February, when the markets are otherwise practically bare of new potatoes.

The cereal crops under test included corn, popcorn, barley, oats, rye, and sorghum. There were also planted some 27 varieties of green-manure crops and 28 lots of soybeans.

Twenty-one different varieties of vegetables were planted. The small fruits under test included strawberries, dewberries, Logan blackberries, akala berries, pohas, and 17 varieties of grapes, of which the Isabella appears to be the only one adapted to the local conditions. Fruit trees included avocado, mango, mulberry, prune, nectarine, orange, lime, Bartlett pear, pecan, Persian (English) walnut, almond, Japanese persimmon, apple, cherimoya, loquat, fig, longan, pomegranate, Macadamia nut, guava, mamey apple, star-apple, mountain apple, and mabolo.

Planting material of the more promising forage crops, vegetables, and small fruits was distributed to cooperators who wished to make tests under their local conditions.

The year as a whole was characterized by a very low rainfall. During the 6-month period from May 1 to October 31, 1933, the following precipitation (all in the form of light showers) was recorded: Haleakala substation, 4.93 inches; Olinda, 1.71; Ukelele, 2.07; Mountain Paddock, 0.96; Puu Nianiau, 4.33.

KONA SUBSTATION

The Kona substation, Island of Hawaii, continued to devote its principal energies to the investigation of the various problems affecting the coffee industry. An additional tract of 1.66 acres of adjoining land was obtained during the year and devoted to the testing of different species and varieties of coffee obtained from various parts of the Tropics.

The coffee projects under way had to do with species and variety testing, culture, pruning, and fertilizer-requirement studies, as well as the determination of the best methods, seasons, and stocks for budding and grafting operations. Evidence points to the desirability of utilizing only budded and grafted stock to insure uniformity of yield and a standardized product in connection with coffee and Macadamia nuts, as well as avocado, mangoes, and citrus.

Variety and cultural tests were continued in connection with numerous species and varieties of miscellaneous fruits thought to be of possible promise. These plantings include breadfruit, cashew nuts, cherimoya, figs, Japanese persimmons, litchi fruits, olives, passion fruit, sweetpotato, tomato, and various cover crops which, with the sweetpotatoes and tomatoes, have been intercropped between the rows of young fruit trees.

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HAWAII AGRICULTURAL EXPERIMENT STATION, HONOLULU

[Under the joint supervision of the Office of Experiment Stations, U. S. Department of Agriculture, and the University of Hawaii]

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1 Appointment effective Apr. 1, 1934.
2 Appointment effective Feb. 16, 1934.
3 Designated Sept. 1, 1933.